Oil plume simulations: Tracking oil droplet size distribution and fluorescence within high-pressure release jets

R.N. Conmy[1], B. Robinson[2], T. King[2], M. Boufadel[3], S. Ryan[2], C. McIntyre[2], M. I. Abercrombie[4], K. Lee[2,5]

[1]U.S. Environmental Protection Agency, Office of Research and Development, NRMRL

[2] Bedford Institute of Oceanography, Dept. Fisheries and Oceans Canada

[3] New Jersey Institute of Technology

[4]University of South Florida, College of Marine Science

[5] CSIRO Australia

International Oil Spill Conference 2017
May 15-18, 2017
Long Beach, California
Submitted abstract on 5/16/16 ID # 2017-137

Optical measurements have been used during oil spill response for more than three decades to determine oil presence in slicks and plumes. Oil surveillance approaches range from simple (human eyeball) to the sophisticated (sensors on AUVs, aircraft, satellites). In situ fluorometers and particle size analyzers were deployed during the Deepwater Horizon (DWH) Gulf of Mexico oil spill to track shallow and deep subsea plumes. Uncertainties regarding instrument specifications and capabilities during DWH necessitated performance testing of sensors exposed to simulated, dispersed oil plumes. Seventy two wave tank experiments were conducted at the Bedford Institute of Oceanography. Simulated were oil releases with varying parameters such as oil release rate, oil temperature (reservoir temp ~ 80 °C), water temperature (<8 °C and >15 °C), oil type, dispersant type (Corexit 9500 and Finasol OSR52) and dispersant to oil ratio (DOR). Plumes of Alaskan North Slope Crude, South Louisiana Crude and IFO-120 were tracked using in situ fluorescence, droplet size distribution (DSD; LISST 100X), total petroleum hydrocarbons (TPH), benzene-toluene-ethylbenzene-xylene (BTEX) and excitation-emission matrix spectroscopy. Results offer valuable information on the behavior and dispersibility of oils over a range of viscosity, DOR and environmental conditions. Findings have implications for fate and transport models, where DSD, chemistry and fluorescence are all impacted by release variables. Research supported by the Bureau of Safety and Environmental Enforcement.

HASP #: 2014-033 Rev 2	Expiration Date: 06/30/2017

Health and Safety Plan

Title: Oil Spill Research Including Work with Dispersants, Surface Washing Agents (SWAs), and Oil Degrading Microbes

Principal Investigator(s): Robyn Conmy, Edith Holder
Office: ORD
Laboratory: NRMRL
Division: LRPCD
Branch: ESMB
Building: AWBERC
Room/Lab #: 703, 701, 708, Constant Temperature Room 710, 409, 514

Approvals

I have read and approve the attached Health and Safety Plan in conformance with the ORD Facility Chemical Hygiene Plan and Health & Safety Plan Policy. I certify that the workplace hazards, routinely and non-routinely encountered by employees, during the described activities, and for which Personal Protective Equipment has been provided, have been assessed for the determination of Personal Protective Equipment required, in compliance with 29 CFR 1910 Subpart I.

	Name	Phone	Signature / Date
Preparer	Edith Holder	569-7178	5/19/2016 X Edith Holder Edith Holder Signed by: EDITH HOLDER (affiliate)
Principal Investigator	Robyn Conmy	569-7090	ROBYN CONMY Digitally signed by ROBYN CONMY DN: c=US, o=U.S. Government, ou=USEPA, ou=Staff, cn=ROBYN CONMY, dnQualifier=0000041674 Date: 2016.05.19 13:51:00 -04'00'
Immediate Supervisor	Joseph Schubauer-Berigan	569-7734	
PTSI On-Site Manager	Raghu Venkatapathy	569-7077	RAGHURAMAN VENKATAPATHY (affiliate) Digitally signed by RAGHURAMAN VENKATAPATHY (affiliate) Date: 2016.05.19 13:09:57 -04'00'
Co-PI / Contract Manager			
SHEM Approval	Steve Musson	569-7969	

Additional information on the completion of a Health & Safety Plan may be found at the SHEM Intranet Site.

Laboratory / Field Staff Concurrence

I have read, understood and will comply with all the requirements of the attached Health and Safety Plan, SDSs, and the rules contained in the U. S. EPA- Facilities Chemical Hygiene Plan. I have also had the opportunity to ask any questions, and had my questions satisfactorily answered prior to my beginning work under this plan.

Name (Print)	Employer (EPA, ORISE, Contractor name, etc.)	Lab (L), Field (F), or Both?	Signature	Date
Edith Holder	Contractor	L	See cover page	

Project Description

Unintentional releases of oil into coastal waters may result in oil becoming stranded on shorelines. Oil that reaches the shoreline can have a severe effect on the local environment, including toxic exposures and smothering of biota in direct contact with the oil. Surface washing agents (SWAs) are chemical agents intended to enhance the removal of oil from shoreline surfaces, thereby minimizing detrimental effects to impacted biota. Dispersants are chemical agents intended to break up the oil by reducing the oil-water interfacial surface tension, which will eventually promote dispersion of oil droplets into the water column. It is necessary to evaluate the potential benefits as a remediation aide of these two classes of compounds as well as the long term ramifications to the environment of their use.

Indigenous bacteria have the capability of removing oil components by biodegradation. The capability of populations from different sources to biodegrade different oils as well as the interactions of microbial populations to the various dispersants and SWAs is a subject for current study.

Laboratory Activities

This laboratory has done previous studies looking at the effects of dispersants, SWA, bioremediation products, and microbes enriched from sediments and water. From an earlier QAAP 386-Q11-0, endorsed 7 June 2002: "The U.S. Environmental Protection Agency's (EPA) Oil Spill Research Program encompasses several major objectives: 1) to develop and/or conduct scientifically sound and defensible protocols for testing the effectiveness of commercial bioremediation products on crude and refined oil in various environments, 2) to develop and/or conduct chemical and microbiological methods for characterizing changes in the chemical and biological composition of oil-contaminated matrices, such as beach material, soil, or water; and 3) to conduct research defining the proper conditions needed to bring about oil spill cleanup in the field. Research to address these objectives was initiated under Quality Assurance Project Plan (QAPP)ID No. C-781-B. The work performed earlier used Alaskan oil and Alaskan cultures. The current research will include Gulf of Mexico oil and cultures, as well as other oils of interest such as Dilbit and freshwater cultures from the Enbridge spill in Kalamazoo, MI. If new spills occur, oil and sediments from the impacted site may come under investigation.

Analysis of oil in water will be measured by Fluorometry. Samples of oil that have been extracted into either methylene chloride or hexane will be measured using UV/Vis Spectrophotometry or GC/MS. The current work will use the methods listed in the following QAPPs and HASPS which can be found on the L drive under L:Public\NRMRL-PUB\Holder\OilSpill\HASP&QAPP:

\QAPP_SWA_2014\WA 0-05 L10539-QP-1-6.pdf Validation and Testing of a Surface Washing Agent Testing Protocol containing Standard Operating Procedure for Testing effectiveness of Surface Washing Agents Listed on the National Contingency Plan Product Schedule, February 2016

\QAPP_BFT_2013\WA 05 QAPP for Development and Revision of Procedures for the CFR_20141024.pdf November 2015
\L14866-QP-1-6 Appendix A final 19Sep2013.docx
Oil Dispersant Testing, Standard Operating Procedure for Determining Effectiveness of Oil Dispersants Using the Baffled Flask Test, May 2013

L14866-QP-1-6 Appendix B final 19Sep2013.docx
Bioremediation Product Testing, Standard Operating Procedure for the Bioremediation Agent Effectiveness Test Protocol, May 2013
\L14866-QP-1-6 Appendix C final 19Sep2013 Oil Analysis SOPs, GC/MS procedures, May 2013
SOP 1: Glassware Cleaning Procedure for Oil Spill Projects
SOP 2: Preparation of Surrogate Recovery Standards
SOP 3: Preparation of Internal Standard Solution
SOP 4: Preparation of Working Standards, Check Standards, and Oil Standards for GC/MS Consistency.
SOP 5: GC/MS Method for the Analysis of Crude Oil Samples

\QAPP_Tox_2015\L21545-QP-1-0 QAPP Crude Oil Toxicity.docx July 2015
Addendum17Nov_L21545-QP-1-0

A QAPP for specific research utilizing fluorescence spectrometry, GC/FID, particle size distribution is in development.
\FDOM analysis.doc Standard Operating Protocol for Fluorescent Dissolved Organic Matter (FDOM)

A majority of the analytical methods are common to multiple projects and activities conducted within the oil spill program. The analytical work covered under this HASP includes experiments with oil dispersants, surface washing agents (SWA), and oil degrading bacteria enriched from natural sources. Abiotic testing of the dispersants and SWA testing will utilize different oils and different products, varying parameters of application, temperature, weathering effects, and substrate. Biotic experiments will include biodegradation studies using a sacrificial shake flask experimental design.

The instruments that will be used for measuring oil components are a Shimadzu UV 1800 Spectrophotometer, Horiba Fluorolog3 Spectrofluorometer, WetLabs, Inc. ECO Submersible Fluorometer, Sequoia Scientific LISST 100X, Agilent 7890B Gas Chromatograph / Flame Ionization Detector, and Agilent 6890 Gas Chromatograph with a 5973 Mass Spectrometer Detector. For all experiments, solvent (water, dichloromethane (DCM) or hexane) extracts of oil will be produced for analytical measurement.

Room 703 is the base lab for the various activities. The GC/MS is located in room 409, and the GC/FID is in room 514 CTR 710 will be used for 5°C work and 708 for work at 25°C. Storage of oil is in 703, storage of frozen samples is in 701, and storage of refrigerated samples is in 701 and CTR 710.

The full notice regarding dichloromethane (DCM) is given at the end of this document.

Physical Hazards Summary

The physical hazards marked below have been identified as present during the performance of the project. Job hazards for specific steps are described in the Job Hazard Analysis Table at the end of the HASP. ***Check the Lab column for lab hazards and Field column for hazards applicable to field work.***

Physical Hazards	**Lab**	**Field**
Electrical Hazards	X	
Radioactive Materials – requires RSO approval of HASP		
Non-Ionizing Radiation		
Ionizing Radiation – requires RSO approval of HASP		
Heavy Lifting		
Vibration		
UV light/radiation	X	
Noise		
Temperature	X	
Illumination		
Compressed Gas	X	
Sharp Objects / Tools		
Slips, Trips, Falls		
Other (Specify): rotating equipment – laboratory shaker	X	

PPE Summary

The PPE items marked below are required to be utilized during performance of the project. PPE requirements for specific steps are described in the Job Hazard Analysis Table at the end of the HASP. ***Check the Lab column for lab hazards and Field column for hazards applicable to field work. *Minimum dress for entering a laboratory is closed toed shoes, long pants (waist to ankles), shirt, and safety glasses. Additional PPE shall be required based upon activities.***

PPE Type	**Lab***	**Field**
Face / Eye Protection		
Safety Glasses w/ Side Shields	X	
Chemical Splash Goggles	X	
Face Shield	X	
Other (specify)		
Ear Protection		
Ear Plugs (Foam Inserts)		
Ear Muffs		
Both Ear Plugs and Ear Muffs		
Other (specify)		
Hand Protection		
Nitrile disposable exam	X	
Latex disposable exam		
Butyl disposable exam		
Silver Shield® or Ansell Barrier Gloves	X	
Thermal (Heat Resistant) Gloves	X	
Cryogen Gloves		
Cotton Gloves		
Leather Gloves		
Cut Resistant (Kevlar ®)		
Other (specify): Polypropylene Gloves (see FDOM SOP); PVA (better tactile than Silver Shield. Used when splash is not expected)	X	

PPE Type	Lab*	Field
Protective Clothing		
Lab Coat	X	
Lab Apron		
Jumpsuit/Coveralls		
Traffic Safety Vests		
Shoe covers		
Safety Shoes: Steel Toe Boots and Shoes		
Safety Shoes: Metatarsal Boots		
Safety Shoes: Slip Resistant Boots and Shoes		
Oversleeves		
Other (specify)		

Respiratory Protection

Employees Wearing Respiratory Protection must be enrolled in the Respiratory Protection Program, must be medically cleared to wear a respirator, and have annual training before wearing a respirator. The respirators marked below (X) are required to be utilized during performance of the project. Respirator requirements for specific project steps are described in the Job Hazard Analysis Table at the end of the HASP.

No respirators/dust masks are required for this project. Respirator/dust mask use is not authorized. Contact the SHEM Office for requirements if respirator/dust mask use becomes necessary.	X
N-95 Filtering Facepiece/Dust Mask	
P-100 Filtering Facepiece/Dust Mask	
Air Purifying Half Face Respirator	
Air Purifying Full Face Respirator	
Airline Supplied Air Respirator	
SCBA	
Powered Air Purifying Respirator (PAPR)	

The following cartridges shall be used: N/A
The cartridges shall be changed/removed from service on the following schedule: N/A

Equipment Requirements

The safety equipment/engineering controls marked below(X) are required to be utilized during performance of the project. Requirements for specific steps are described in the Job Hazard Analysis Table at the end of the HASP.

Chemical Fume Hood	X
Biological Safety Cabinet	
Walk-in / Bulking Hood	
Radiological Fume Hood	
Balance Enclosure	
Clear Air Bench (laminar flow hood)	
Spot Ventilation Unit (Snorkel)	
Local Exhaust Ventilation	

Canopy Hood	
Refrigerator / Freezer	X
Deep Freezer	X
Other (specify): spectrophotometer / shaker / GC/MS/ drying oven and muffle furnace	X

Chemicals To Be Used

EPA utilizes an online service, Chemwatch, to provide Safety Data Sheets (SDS) to employees.
http://jr.chemwatch.net/chemwatch.web
Account: epa User Name*: Everyone* Password*: 120270.*

If the SDS is not available through Chemwatch, a hardcopy of the manufacturer supplied SDS must be submitted to the SHEM office for upload to the Chemwatch system. **ALL fields must be completed in the table below for all chemicals used in the project.**

Item #	Chemical Name	CAS#	Project Use	Disposal Method for Unused Chemicals	Notes
			Ex. Reagent, Standard, or Specific task #	S = Sink T = Trash W = Chemical Waste Program R = Return to Vendor	(EPA waste codes, special hazards, ingredients, etc.)
1	Dichloromethane	75-09-2	Solvent	W	U080, F002; See special OSHA information at end of HASP. Carcinogen
2	Hexane	110-54-3	Solvent	W	
3	Petroleum Crude Oil, listed below	8002-05-9	Reagent	W	
4	Various products from NCPPS, listed below	Mixtures	Dispersants and SWA	W	
5	Sodium Sulfate	7757-82-6	Reagent	W	
6	Sea Salts (Sigma) (or Instant Ocean)	Mixture	Media	S or T	
7	Bushnell-Haas Broth	Mixture	Media	S or T	Contains: $MgSO_4$, $CaCl_2$, KH_2PO_4, K_2HPO_4, NH_4NO_3
8	Sodium Chloride	7647-14-5	Media	S	
9	Potassium Chloride	7447-40-7	Media	S	
10	Potassium Bromide	7758-02-3	Media	W	
11	Sodium Borate	1303-96-4	Media	S	
12	Magnesium Chloride	7791-18-6	Media	S or T	
13	Calcium Chloride	10043-52-4	Media	S or T	
14	Strontium Chloride	10476-85-4	Media	W	
15	Sodium Bicarbonate	7757-82-6	Media	S or T	
16	Potassium Nitrate	7757-79-1	Media	W	D001 - oxidizer
17	Iron Chloride	10025-77-1	Media	W	
18	Sodium Tripolyphosphate	7722-88-5	Media	W	
19	Sodium Hydroxide	1310-73-2	reagent	W	D002

Item #	Chemical Name	CAS#	Project Use	Disposal Method for Unused Chemicals	Notes
			Ex. Reagent, Standard, or Specific task #	**S = Sink T = Trash W = Chemical Waste Program R = Return to Vendor**	**(EPA waste codes, special hazards, ingredients, etc.)**
20	Hydrochloric Acid	7647-01-0	Reagent, acid washing, fluorometry	W	
21	Acenaphthene	83-32-9	standard	W	
22	Acenaphthylene	208-96-8	standard	W	
23	Benzo(a)anthracene	56-55-3	standard	W	
24	Biphenyl	92-52-4	standard	W	
25	2,6-Dimethylnaphthalene	581-42-0	standard	W	
26	3,6-Dimethylphenanthrene	1576-67-6	standard	W	
27	1-Methylnaphthalene	90-12-0	standard	W	
28	2-Methylphenanthrene	2531-84-2	standard	W	
29	2,3,5-Trimethylnaphthalene	2245-38-7	standard	W	
30	Decane	124-18-5	standard	W	
31	Undecane	1120-21-4	standard	W	
32	Dodecane	112-40-3	standard	W	
33	Tridecane	629-50-5	standard	W	
34	Tetradecane	629-59-4	standard	W	
35	Pentadecane	629-62-9	standard	W	
36	Hexadecane	544-76-3	standard	W	
37	Heptadecane	629-78-7	standard	W	
38	Octadecane	593-45-3	standard	W	
39	Nonadecane	629-92-5	standard	W	
40	Eicosane	112-95-8	standard	W	
41	Heneicosane	629-94-7	standard	W	
42	Docosane	629-97-0	standard	W	
43	Tricosane	638-67-5	standard	W	
44	Tetracosane	646-31-1	standard	W	
45	Pentacosane	629-99-2	standard	W	
46	Hexacosane	630-01-3	standard	W	
47	n-Heptacosane	593-49-7	standard	W	
48	Octacosane	630-02-4	standard	W	
49	n-Nonacosane	630-03-5	standard	W	
50	n-Triacontane	638-68-6	standard	W	
51	n-Hentriacontane	630-04-6	standard	W	
52	n-Dotriacontane	544-85-4	standard	W	
53	n-Tritriacontane	630-05-7	standard	W	
54	n-Tetratriacontane	14167-59-0	standard	W	
55	n-Pentatriacontane	630-07-9	standard	W	
56	Naphthalene	91-20-3	standard	W	
57	Fluorene	86-73-7	standard	W	
58	Dibenzothiophene	132-65-0	standard	W	

Item #	Chemical Name	CAS#	Project Use	Disposal Method for Unused Chemicals	Notes
			Ex. Reagent, Standard, or Specific task #	**S = Sink T = Trash W = Chemical Waste Program R = Return to Vendor**	**(EPA waste codes, special hazards, ingredients, etc.)**
59	Phenanthrene	85-01-8	standard	W	
60	Fluoranthene	206-44-0	standard	W	
61	Pyrene	129-00-0	standard	W	
62	Chrysene	218-01-9	standard	W	
63	Benzo(b)fluoranthene	205-99-2	standard	W	
64	Benzo(k)fluoranthene	207-08-9	standard	W	
65	Benzo(e)pyrene	192-97-2	standard	W	
66	Benzo(a)pyrene	50-32-8	standard	W	
67	Perylene	198-55-0	standard	W	
68	Indeno(1,2,3-cd)pyrene	193-39-5	standard	W	
69	Dibenzo(a,h)anthracene	53-70-3	standard	W	
70	Benzo(g,h,i)perylene	191-24-2	standard	W	
71	Pristane	1921-70-6	standard	W	
72	Phytane	638-36-8	standard	W	
73	Anthracene	120-12-7	standard	W	
74	Benzo[*b*]naphtho[2,1[*d*]thiophene	239-35-0	standard	W	
75	5b-Cholestane	481-20-9	standard	W	
76	5a-Androstane	438-22-2	standard	W	
77	Hopane	1176-44-9	standard	W	
78	D22 n-Decane	16416-29-8	standard	W	
79	D34 n-Hexadecane	15716-08-2	standard	W	
80	D42 n-Eicosane	62369-67-9	standard	W	
81	D62 n-Triacontane	93952-07-9	standard	W	
82	D8-Naphthalene	1146-65-2	standard	W	
83	D10-Anthracene	1719-06-8	standard	W	
84	D12-Chrysene	1719-03-5	standard	W	
85	D12-Perylene	1520-96-3	standard	W	
86	D36-Heptadecane	39756-35-9	standard	W	
87	D50-Tetracosane	16416-32-3	standard	W	
88	D66-Dotriacontane	62369-68-0	standard	W	
89	D10-1-methylnaphthalene	1517-22-2	standard	W	
90	D10-Phenanthrene	1517-22-2	standard	W	
91	D10-Pyrene	1718-52-1	standard	W	
92	Ph buffers 4, 7, and 10	Varies	Calibration	S	
93	Nitric Acid	7697-37-2	pH adjustment/ sand washing	W	D001, D002
94	Methanol	67-56-1	fluorometry	W	U154, D001, F003
95	Rhodamine B	81-88-9	fluorometry	W	
96	Ethylene Glycol	107-21-1	fluorometry	W	
97	Quinine Sulfate Dihydrate	6119-70-6	fluorometry	W	

Item #	Chemical Name	CAS#	Project Use	Disposal Method for Unused Chemicals	Notes
			Ex. Reagent, Standard, or Specific task #	**S = Sink T = Trash W = Chemical Waste Program R = Return to Vendor**	**(EPA waste codes, special hazards, ingredients, etc.)**
98	Sulfuric Acid	7664-93-9	Fluorometry, pH adjustment	W	D002
99	Dimethyldichlorosilane (5%) in Toluene	Mixture	Silanizing glassware	W	
100	Sodium Azide	26628-22-8	Microbial Growth Inhibitor	W	P105
101	Magnesium Sulfate	7487-88-9	Media	S or T	
102	Manganese Sulfate	10034-96-5	Media	S or T	
103	Boric Acid	10043-35-3	Media	S or T	
104	Zinc Sulfate	7446-20-0	Media	S or T	
105	Ammonium Molybdate	12054-85-2	Media	S or T	
106	Potassium Hydrogen Phosphate	7758-11-4	Media	S or T	
107	Potassium dihydrogen Phosphate	7778-77-0	Media	S or T	

Current Inventory of Crude Oils Line Item # 3 (May 2016)			
Anadarko	Dilbit, WCS	Harmony	PXP 02
ANS	Doba	IFO 120	Rock
ANS 521	Elly	IFO 380	South Louisiana
Arabian Light	Endicott	North Star	Sweet Synthetic
BHP Billiton	Endicott (18% evaporated)	PER 038	Terra Nova
Bonnie Light	Esgravos	PER 040	Venoco E-10
Bunker C	FO2	Prudhoe Bay	Venoco E-19
Dilbit, Cold Lake	Fuel 6	PXP 01	Dorado

Current Inventory of NCPPS Oil Spill Dispersants Line Item # 4 (May 2016)			
Accell Clean DWD	FFT Solution	NEOS AB3000	Saf-Ron Gold
Corexit 9500	Finasol OSR52	Nokomis 3-AA	SX-100
Dispersit SPC1000	JD-2000	Nokomis 3-F4	ZI-400

Current Inventory of NCPPS Oil Spill Surface			
ADP7	Enviroclean	Naturama G3 A-5	Sandklene 950
Aquaclean	EPA Oil Field Solution™	Nokomis 5W	SC-1000
BG-Clean 401	F500	Nontox SWA	Simple Green
Biosolve	Gold Crew SW	Petro-Clean	Spillclean
CleanGreen Planet Wash	Green Beast	Petroluxus	Superall #38
Corexit 9580	Jep Marine Clean	Petrotech 25	
Cytosol	Marine Green Clean	Premier 99	
Dynamic Green	Marine Green Clean Plus	Procleans PCR 107	

Biological Research *(indicate Yes or No)*

Does the project in any way involve manipulation of recombinant DNA?	No

If yes, are all proposed activities specifically exempted from the NIH Guidelines for Research Involving Recombinant DNA Molecules?	
Does the project in any way involve human subjects or biological materials obtained from human subjects?	No
If yes, is the project exempt from the Health and Human Services Policy for Protection of Human Subjects?	
Does the project involve animals requiring Institutional Animal Care & Use Committee (IACUC) approval? (includes vertebrate & invertebrates animals)	No

Biological Agents

The Biosafety Level (BSL) and Animal Biosafety Level (ABSL) refer to specific combinations of work practices, safety equipment, and facility design elements utilized to minimize exposure of workers and the environment to infectious agents. Principal Investigators must perform an agent risk assessment to determine the BSL. Indicate N/A if not applicable to project.

Item #	Biological Agent (list all that apply)	BSL #	Source of Biological Agent	Vaccination Required?
1	Oil degrading bacteria isolated from environmental samples	1	Water or sediments	no

Waste Management

Identify process/research derived samples and wastes and indicate the intended disposal method. Hazardous Waste identification and Treatability study exemptions per 40 CFR Part 261 as reviewed in annual SHEM Hazardous Waste Management training.

	Yes	No
Will Hazardous Waste Be Generated?	X	
Will the Treatability Exemption be Utilized (i.e. will materials from an outside location that would be considered hazardous waste		X

DCM, hexane, methanol, and crude oil wastes (dissolved in DCM) from analytical samples collected via separatory funnel, standards, and glassware rinsate should be disposed of through the SHEM hazardous wastes program due to solvent, oil and PAH contents. After washing gravel and sand with DCM, the DCM is drained into the waste container and the substrate is placed in the fume hood to allow the remaining DCM to evaporate off, before disposing of the cleaned substrate in the garbage.

Spent silanizing solution should be disposed through the SHEM hazardous waste program.

Original chemical reagents will be disposed as indicated in the chemical use table.

Any remaining fresh or seawater will be disposed of down the sink drain because no known hazardous wastes are involved.

Aqueous waste remaining after removal of DCM using a separatory funnel may be sink disposed. Any remaining DCM is placed in a hazardous waste container before dumping remaining water to sink.

Acid solution from sand/gravel cleaning will be collected and neutralized using sodium hydroxide to a pH between 5 and 9 and then disposed of down the sink.

<u>Sample Management</u>

Explain how samples will be identified and labeled for storage (if not immediately discarded) and eventual disposal. Sample contents must be clearly displayed. Include storage location and how long samples must be retained.

All samples will be labeled with sample descriptors including date, analyst, and constituents (solutes and solvents). They will be stored in the refrigerators in 701 or CTR710. They will be kept until data is approved and then disposed of using the Chemical Waste Program. Any enriched bacterial consortia will be frozen and kept in the -80 freezer in 701. They may be maintained indefinitely.

Hexane containing samples are flammable and should only be stored in refrigerators or freezers designed and labeled as approved for flammable material storage.

<u>Spill Response</u>

Describe procedures for managing spills of specific hazardous chemicals, both small and large. General spills may be addressed by reference to the Chemical Hygiene Plan.

Small spills shall be wiped up by project personnel wearing proper PPE and the absorbent material bagged, labeled as to its hazardous constituents, then submitted to the SHEM Waste Program for proper disposal. In the event of a large solvent spill, SHEM will be contacted via x7997 or by way of security per the Chemical Hygiene Plan.

The spill of any bacterial consortia that have been enriched from environmental samples will be doused with either a 10% chlorine solution or 70% ethanol solution, allowed to sit for ~ 10 minutes and then wiped up. The wipes used will be placed in a biohazard bag for autoclaving.

The SHEM program office provides spill kits for all laboratory use. Staff should review the list and determine the location of the nearest spill kit. *(Delete those areas not applicable)*

AWBERC	G through 7 floors in the freight elevator lobby

In addition, the lab maintains spill kits in the following location: 703- on the left side of the lab near the door.

The biological spill kit is located: N/A

Authorized Personnel

Training and medical monitoring requirements will vary depending on the complexity and materials used in the process. Therefore, only personnel trained and monitored will be permitted to work under this plan. To be "authorized", employees must have completed the training and screenings selected below.

Mandatory for all researchers	
Initial Laboratory Safety	**X**
Current Chemical Hygiene Plan Laboratory Safety Refresher	**X**
Hazardous Waste Management (RCRA)	**X**
Project/Task Dependent	
Medical Surveillance	**X**
Respiratory Protection	
Biosafety / Blood borne Pathogens	
Initial Field Safety and/or 8 hour field safety refresher training in the fiscal year	
40 - hour HAZWOPER and/or 8 hour HAZWOPER refresher in the last 12 months	
Hearing Protection	
First Aid / CPR / AED	
DOT Hazardous Materials Awareness/Shipment	
Radiation Safety	
EPA Driver's Training	
EPA Boat Safety Training	
EPA Nanomaterials Health and Safety Awareness Training	
Other (specify) – Dichloromethane information (See below)	X

References:

General Activities
Job Hazard Analysis, Controls, and PPE

Job Step/Operation	Room / Area	Potential Hazards/Risks	Recommended Action/Procedure	PPE Required
Preparation of artificial seawater and freshwaters	703	Little chemical hazard as it consists of salts. Irritants	Prepare chemical solutions in a CFH where possible	Lab coat, safety glasses with side shields, nitrile gloves, closed-toe shoes
Use of freezer	701	Thermal burns from the ultra low freezer	Use caution when handling items from the freezer	Thermal protective gloves Lab coat, safety glasses with side shields, nitrile gloves, closed-toe shoes
Use of autoclave	380	See chemical hygiene plan for Autoclave Hazard Analysis	See chemical hygiene plan for Autoclave Hazard Analysis	See chemical hygiene plan for Autoclave Hazard Analysis
Use of centrifuge		See chemical hygiene plan for Centrifuge Hazard Analysis	See chemical hygiene plan for Centrifuge Hazard Analysis	See chemical hygiene plan for Centrifuge Hazard Analysis
Preparation of dilute acid from concentrated acid for performing pH adjustments	703	Splash – chemical burns to exposed skin	Prepare solution in a chemical fume hood	Face shield – Lab coat, safety glasses with side shields, nitrile gloves, closed-toe shoes
Use of drying oven and muffle furnace	703	Burns	Caution with hot glassware. Let muffle furnace completely cool down before removing glassware.	Thermal protective gloves
CTR 710		Limited ventilation – build up of chemical vapors, inhalation of DCM and other toxic and carcinogenic chemical vapors	No open chemical container work should be performed in CTR 710. All containers should remain closed. Samples should be moved to a room with a CFH if necessary to open.	Lab coat, safety glasses with side shields, nitrile gloves, closed-toe shoes

SOP 1 - Glassware Washing
Job Hazard Analysis, Controls, and PPE

Glassware Washing * includes supplies, utensils and containers in contact with soil, extraction fluid, and/or leachate			
Sequence of Basic Job Steps	**Potential Hazards**	**Recommended Action or Procedure**	**PPE Required**
Rinse loose debris from the surface	• Cross contamination from glassware to personnel – potential exposure • Splash or spray from rinsing – potential exposure • Potential breakage of glassware from cracks or defects – cuts / lacerations / contamination	• Inspect glassware before cleaning for cracks or other damage – discard in broken glass container if damage is noticed or suspected • use low pressure water to avoid splash and/or aerosolization of the contaminants • if any glassware is broken during cleaning – only remote means should be used to pick up any broken glass	• minimum of safety glasses, laboratory coat, and gauntlet length nitrile gloves
Wash with brush, soap, and water. Triple rinse with water. Soak in soap bath.	• Cross contamination from glassware to personnel – potential exposure • Splash or spray from rinsing – potential exposure • Potential breakage of glassware from cracks or defects – cuts / lacerations / contamination	• Inspect glassware before cleaning for cracks or other damage – discard in broken glass container if damage is noticed or suspected • use low pressure water to avoid splash and/or aerosolization of the contaminants • if any glassware is broken during cleaning – only remote means should be used to pick up any broken glass	• minimum of safety glasses, laboratory coat, and gauntlet length nitrile gloves
Drying object using drying racks	• potential for dropping the glassware, tools, etc. – breakage, spillage, contact with other surfaces • slip / trip / fall hazards from water spillage or splashing from the rinsing process	• ensure that the drying racks are placed to reduce any ergonomic hazard from stretching, or repetitive motion • follow the established emergency procedures for injuries or spills including immediate notification of your supervisor or 911 for life threatening cases (also x7777, direct contact to security)	• minimum of safety glasses, laboratory coat, and gauntlet length nitrile gloves

SOP 2 -Preparation of a Surrogate Recovery Standard
SOP 3 - Preparation of Internal Standard Solution
SOP 4 - Preparation of Working Standards, Check Standards, and Oil Standards for GC/MS
Job Hazard Analysis, Controls, and PPE

Job Step/Operation	Potential Hazards/Risks	Recommended Action/Procedure	PPE Required
Weigh reagents **Dissolve reagents / wash beakers using methylene chloride** **Transfer the solution**	Reagents listed contain materials that are listed as carcinogens or potential for causing cancer, irritants, and are photosensitizers. Potential for illness upon inhalation and / or skin contact (chemical dermatitis, increase probability for sunburn)	Prepare the reagents / standards in a chemical fume hood only. Handle reagents in the smallest quantities possible and do not cross contaminate. DCM – attempt to not 'pour' DCM as the ST is low and tends to spread. Use the sash on a CFH for splash protection where possible. Review OSHA Regulated Substance Awareness for DCM.	Double gloves - Wear normal length nitrile gloves over silvershield gloves to maintain dexterity; Lab coat, safety glasses with side shields, and closed-toe shoes.

Pipetting	see chemical hygiene plan for pipetting recommendations	See chemical hygiene plan for pipetting recommendations	Double nitrile gloves and / or silvershield gloves (where dexterity is not an issue). Lab coat, safety glasses with side shields, and closed-toe shoes.

SOP 5 - GC/MS Method for the Analysis of Crude Oil
Job Hazard Analysis, Controls, and PPE

Job Step/Operation	Potential Hazards/Risks	Recommended Action/Procedure	PPE Required
Compressed Gas Usage (Helium)	See Chemical Hygiene Plan – JHA for Compressed Gas Cylinders	See Chemical Hygiene Plan – JHA for Compressed Gas Cylinders	See Chemical Hygiene Plan – JHA for Compressed Gas Cylinders
Solvent / standard / stock preparation	See JHA for SOP 2, 3, and 4)	See JHA for SOP 2, 3, and 4)	See JHA for SOP 2, 3, and 4)
GC Operation	Compressed Gases GC venting of toxic analytes	Ensure GC exhaust is routed to laboratory ventilation.	Lab coat, safety glasses, protective gloves

SOPs - Analysis of Oil Concentration in DCM by UV/Vis Spectrophotometry and Spectrofluorometry
Job Hazard Analysis, Controls, and PPE

Job Step/Operation	Potential Hazards/Risks	Recommended Action/Procedure	PPE Required
Add DCM to crude oil **Syringe use** **Extraction with DCM (shaking and venting)** **Dispense / transfer solutions**	Reagents listed contain materials that are listed as carcinogens or potential for causing cancer, irritants, and are photosensitizers. Potential for illness upon inhalation and / or skin contact (chemical dermatitis, increase probability for sunburn)	Prepare the reagents / standards in a chemical fume hood only. Handle reagents in the smallest quantities possible and do not cross contaminate. DCM – attempt to not 'pour' DCM as the ST is low and tends to spread. Use the sash on a CFH for splash protection where possible. Review OSHA Regulated Substance Awareness for DCM.	Double gloves - Wear normal length nitrile gloves over silvershield gloves to maintain dexterity; Lab coat, safety glasses with side shields, and closed-toe shoes.
Pipetting	See chemical hygiene plan for pipetting recommendations	See chemical hygiene plan for pipetting recommendations	Double nitrile gloves and / or silvershield gloves (where dexterity is not an issue). Lab coat, safety glasses with side shields, and closed-toe shoes.
Operation of Spectrophotometer and Fluorometer	UV light exposure	Check for presence of all equipment guards and verify operation.	Nitrile gloves Lab coat, safety glasses with side shields, and closed-toe shoes.

SOP - The Baffled Flask Test for Determining Effectiveness of Dispersants
Extraction of WAFs from Toxicity Testing QAPP
Job Hazard Analysis, Controls, and PPE

Job Step/Operation	Potential Hazards/Risks	Recommended Action/Procedure	PPE Required
Add DCM to crude oil and seawater **Syringe use** **Extraction with DCM (shaking and venting)** **Dispense / transfer solutions**	Reagents listed contain materials that are listed as carcinogens or potential for causing cancer, irritants, and are photosensitizers. Potential for illness upon inhalation and / or skin contact (chemical dermatitis, increase probability for sunburn)	Prepare the reagents / standards in a chemical fume hood only. Handle reagents in the smallest quantities possible and do not cross contaminate. DCM – attempt to not 'pour' DCM as the ST is low and tends to spread. Use the sash on a CFH for splash protection where possible. Review OSHA Regulated Substance Awareness for DCM.	Double gloves - Wear normal length nitrile gloves over silvershield gloves to maintain dexterity; Lab coat, safety glasses with side shields, and closed-toe shoes.
Pipetting	See chemical hygiene plan for pipetting recommendations	See chemical hygiene plan for pipetting recommendations	Double nitrile gloves and / or silvershield gloves (where dexterity is not an issue). Lab coat, safety glasses with side shields, and closed-toe shoes.
Extraction with DCM including shaking and venting	Reagents listed contain materials that are listed as carcinogens or potential for causing cancer, irritants, and are photosensitizers. Potential for illness upon inhalation and / or skin contact (chemical dermatitis, increase probability for sunburn)	Perform extraction in a chemical fume hood only. Handle reagents in the smallest quantities possible and do not cross contaminate. Use the sash on a CFH for splash protection where possible. This should **ONLY** be done in a CFH.	Double gloves - Wear normal length nitrile gloves over silvershield gloves to maintain dexterity; Lab coat, safety glasses with side shields, and closed-toe shoes.
Operation of Spectrophotometer or Spectrofluorometer	UV light exposure	Ensure all equipment guards are present and operable.	Nitrile gloves Lab coat, safety glasses with side shields, and closed-toe shoes.
Use of the shaker	Spills, mechanical issues with equipment	Ensure all equipment guards are present and operable. Ensure a periodic inspection of equipment.	Nitrile gloves Lab coat, safety glasses with side shields, and closed-toe shoes.

SOP - Basket Test for Determining Effectiveness of SWA
Job Hazard Analysis, Controls, and PPE

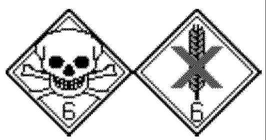
Job Step/Operation	Potential Hazards/Risks	Recommended Action/Procedure	PPE Required
Acid wash of the substrate	burns from acid contact from spills, splashes from bath	Conduct in chemical fume hood	Double nitrile gloves - Wear normal length nitrile gloves inside of elbow length nitrile gloves; Wear a face shield / chemical splash goggles.
Addition of crude oil	Reagents listed contain materials that are listed as carcinogens or potential for causing cancer, irritants, and are photosensitizers. Potential for illness upon inhalation and / or skin contact (chemical dermatitis,	Prepare the reagents / standards in a chemical fume hood only. Handle reagents in the smallest quantities possible and do not cross contaminate. Use the sash on a CFH for splash protection where possible. – see chemical hygiene plan for pipetting recommendations.	Double gloves - Wear normal length nitrile gloves over silvershield gloves to maintain dexterity; Lab coat, safety

	increase probability for sunburn) – see chemical hygiene plan for pipetting recommendations	Review OSHA Regulated Substance Awareness information below for DCM.	glasses with side shields, and closed-toe shoes.
Use of the shaker	skin chemical contact from splash or spill - eye chemical contact inhalation of chemicals contact injury with moving/rotating machinery	Work in a chemical fume hood when preparing reagents. Ensure all caps are tightly sealed. Ensure area is clear before starting shaker. Secure loose fitting clothing to prevent snagging by shaker.	Laboratory coat, and nitrile gloves; wear chemical splash goggles
DCM extraction	Reagents listed contain materials that are listed as carcinogens or potential for causing cancer, irritants, and are photosensitizers. Potential for illness upon inhalation and / or skin contact (chemical dermatitis, increase probability for sunburn)	Perform extraction in a chemical fume hood only. Handle reagents in the smallest quantities possible and do not to not cross contaminate. Use the sash on a CFH for splash protection where possible. This should **ONLY** be done in a CFH.	Double gloves - Wear normal length nitrile gloves over silvershield gloves to maintain dexterity; Lab coat, safety glasses with side shields, and closed-toe shoes.
UV spectrophotometry	eye chemical contact inhalation of chemicals skin chemical contact from splash or spill	Work in a chemical fume hood when handling reagents with respiratory warnings Handle quartz cuvet with secure grip to prevent dropping or breaking	wear a laboratory coat, and nitrile gloves; wear chemical splash goggles

Methylene Chloride / Dichloromethane

Per OSHA regulation 29 CFR 1910.1052, an employer shall provide information and training for each affected employee prior to or at the time of initial assignment to a job involving potential exposure to methylene chloride. Through the use of laboratory fume hoods and procedures outlined in the laboratory chemical hygiene plan and the project health and safety plan, exposure above the regulatory action level is not expected. A full copy of the regulation is available on the OSHA website at www.OSHA.gov or through the SHEM Office. Other information on the safe use of methylene chloride is also available from the SHEM office and OSHA website.

DICHLOROMETHANE	**ICSC: 0058**
Methylene chloride DCM CH_2Cl_2 Molecular mass: 84.9 ICSC # 0058	CAS # 75-09-2 RTECS # PA8050000 UN # 1593 EC # 602-004-00-3 December 04, 2000 Validated

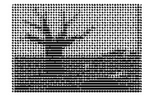


TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Combustible under specific conditions. Gives off irritating or toxic fumes (or gases) in a fire.		In case of fire in the surroundings: use appropriate extinguishing media.
EXPLOSION	Risk of fire and explosion (see Chemical Dangers).	Prevent build-up of electrostatic charges (e.g., by grounding).	In case of fire: keep drums, etc., cool by spraying with water.
EXPOSURE		PREVENT GENERATION OF MISTS! STRICT HYGIENE!	
• INHALATION	Dizziness. Drowsiness. Headache. Nausea. Weakness. Unconsciousness. Death.	Ventilation, local exhaust, or breathing protection.	Fresh air, rest. Artificial respiration may be needed. Refer for medical attention.
• SKIN	Dry skin. Redness. Burning sensation.	Protective gloves. Protective clothing.	Remove contaminated clothes. Rinse and then wash skin with water and soap.
• EYES	Redness. Pain. Severe deep burns.	Safety goggles , face shield or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
• INGESTION	Abdominal pain. (Further see Inhalation).	Do not eat, drink, or smoke during work. Wash hands before eating.	Rinse mouth. Do NOT induce vomiting. Give plenty of water to drink. Rest.

SPILLAGE DISPOSAL	STORAGE	PACKAGING & LABELLING
Personal protection: filter respirator for organic gases and vapours. Do NOT let this chemical enter the environment. Ventilation. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand	Separated from metals (see Chemical Dangers), food and feedstuffs . Cool. Ventilation along the floor.	Do not transport with food and feedstuffs. Xn symbol R: 40 S: (2-)23-24/25-36/37 UN Hazard Class: 6.1 UN Packing Group: III

or inert absorbent and remove to safe place.		

IMPORTANT DATA	**PHYSICAL STATE; APPEARANCE:** COLOURLESS LIQUID , WITH CHARACTERISTIC ODOUR. **PHYSICAL DANGERS:** The vapour is heavier than air. As a result of flow, agitation, etc., electrostatic charges can be generated. **CHEMICAL DANGERS:** On contact with hot surfaces or flames this substance decomposes forming toxic and corrosive fumes. Reacts violently with metals such as aluminium powder and magnesium powder, strong bases and strong oxidants causing fire and explosion hazard. Attacks some forms of plastic rubber and coatings. **OCCUPATIONAL EXPOSURE LIMITS:** TLV: 50 ppm as TWA; A3 (confirmed animal carcinogen with unknown relevance to humans); BEI issued; (ACGIH 2004). MAK: Carcinogen category: 3A; (DFG 2004). OSHA PEL: 1910.1052 TWA 25 ppm ST 125 ppm NIOSH REL: Ca See Appendix A NIOSH IDLH: Ca 2300 ppm See: 75092	**ROUTES OF EXPOSURE:** The substance can be absorbed into the body by inhalation and by ingestion. **INHALATION RISK:** A harmful contamination of the air can be reached very quickly on evaporation of this substance at 20°C. **EFFECTS OF SHORT-TERM EXPOSURE:** The substance is irritating to the eyes , the skin and the respiratory tract . Exposure could cause lowering of consciousness. Exposure could cause the formation of methaemoglobin. **EFFECTS OF LONG-TERM OR REPEATED EXPOSURE:** Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system and liver . This substance is possibly carcinogenic to humans.
PHYSICAL PROPERTIES	Boiling point: 40°C Melting point: -95.1°C Relative density (water = 1): 1.3 Solubility in water, g/100 ml at 20°C: 1.3 Vapour pressure, kPa at 20°C: 47.4	Relative vapour density (air = 1): 2.9 Relative density of the vapour/air-mixture at 20°C (air = 1): 1.9 Auto-ignition temperature: 556°C Explosive limits, vol% in air: 12-25 Octanol/water partition coefficient as log Pow: 1.25

ENVIRONMENTAL DATA	This substance may be hazardous in the environment; special attention should be given to ground water contamination.	

NOTES

Addition of small amounts of a flammable substance or an increase in the oxygen content of the air strongly enhances combustibility. Depending on the degree of exposure, periodic medical examination is suggested. The odour warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. R30 is a trade name. Card has been partly updated in April 2005. See section Occupational Exposure Limits.

Transport Emergency Card: TEC (R)-61S1593

NFPA Code: H2; F1; R0;

ADDITIONAL INFORMATION

IMPORTANT LEGAL NOTICE:	Neither NIOSH, the CEC or the IPCS nor any person acting on behalf of NIOSH, the CEC or the IPCS is responsible for the use which might be made of this information. This card contains the collective views of the IPCS Peer Review Committee and may not reflect in all cases all the detailed requirements included in national legislation on the subject. The user should verify compliance of the cards with the relevant legislation in the country of use. The only modifications made to produce the U.S. version is inclusion of the OSHA PELs, NIOSH RELs and NIOSH IDLH values.

To: Barron, Mace[Barron.Mace@epa.gov]
From: Conmy, Robyn
Sent: Tue 4/12/2016 12:20:54 PM
Subject: RE: reference oil/dispersant scope of work

Hi Mace,

I will speak to the Pegasus contractor today about their request for a quote from Hydrosphere. Since it comes from them, I have no control on copying you on any requests. Will keep you posted though. OEM and I had some luck yesterday in getting Finasol and will be working to get this purchased. No news on Nalco Corexit as of yet though. My hope is that we can at least send 3 of the 4 dispersants for testing in May.

Cheers,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Barron, Mace
Sent: Monday, April 04, 2016 11:04 AM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>

Subject: reference oil/dispersant scope of work

*2 different oils and 4 different dispersants will be tested

*note that chemical dispersants are miscible with water and do not pose the cleaning and residue issues that oils have

*Water accommodated fractions (WAF) and toxicity tests must be conducted according to:

Federal Register 80(14) Thursday, January 2 Part III (www.epa.gov/emergency-response/revisions-national-oil-and-hazardous-substances-pollution-contingency-plan)

We would like two cost estimates:

1) oil only and dispersant only tests (total 24 tests: 12 acute + 12 subchronic; see below)

2) oil + dispersant mixture tests (total 16 acute tests; see below)

COST ESTIMATE 1:

Oil Only tests) range finder + definitive +sampling and shipment for oil chemistry

*48 hr mysid acute (2; one for each oil)

*96 hr menidia acute (2)

Dispersant only tests) range finder + definitive (no chemistry sample)

*mysid acute (4; one for each dispersant)

*menidia acute (4)

*72 hour urchin development (4): can use species of your choice; 72 hour test)

*7 day mysid subchronic (4): no fecundity endpoint is needed

*7 day menidia subchronic (4)

COST ESTIMATE 2:

Oil+dispersant mixture tests) range finder + definitive +sampling and shipment for oil chemistry

*48 hr mysid acute (8): 2oil x 4disperant

*96 hr menidia acute (8)

EP-C-15-010

WA 0-05

Short Title: Biodegradability and toxicity of oil and products

Long Title: Biodegradability and toxicity of oil and dispersants and oil spill product protocol development

WACOR: Robyn Conmy, Ph.D.

Conmy.robyn@epa.gov

513.569.7090

ALT WACOR: Ronald Herrmann

Period of Performance: September 30, 2015 – September 29, 2016

Quality Assurance

All research activities which generate data must follow the guidance of ORD policy and procedures manual section 13.4, *Minimum QA\QC Practices for ORD Laboratories Conducting Research*: PPM 13.4

Research records shall follow the applicable policy for laboratory notebooks, according to ORD policy and procedure manual section 13.2, *Paper Laboratory Records*: PPM 13.2.

When applicable, the contractor shall follow SOPs published by LRPCD at L:\Priv\Cin\NRMRL\LRPCD-SOP\, and SOPs published at the NRMRL@Work SOP webpage: NRMRL SOPs. As SOPs are revised and new SOPs are published, the list of approved SOPs changes, therefore it is important that both web locations be consulted when searching for LRPCD SOPs.

The tasks and subtasks below identify QAPPs which will require revision. QAPP revisions must be reviewed and approved by the LRPCD QA manager before research begins under this contract action.

Section 1-Biodegradation, Toxicity and Chemical Characterization of oils

BACKGROUND

The rising demand, production and shipping of petroleum oils in the U.S. equates to increased risk of spills over land and water. In order to better assess risk to communities and ecosystems, continued research oil weathering, biodegradation rates, toxicity and characterization is needed. Understanding these parameters allows for improved conceptual models dedicated to transport pathways and ultimate fate of spilled oil. Biodegradation is a natural process by which microorganisms such as bacteria, fungi, and yeast break down complex compounds into simpler products, thus removing oil from the environment. But removal and degradation rates are a function of variations in environmental factors and microbial structure. Beyond this, the toxicity of oils also varies and is influenced by oil type, weathering state, and application of oil spill countermeasure products listed on National Contingency Plan Product Schedule. Needed is further evaluation of toxicity and exposure studies.

TASK 1.1 – Biodegradability of Physically and Chemically Dispersed Endicott oil and Corexit Dispersant at Two Temperatures.

Task 1.1 Relevance and Objective: Biodegradation rates of physically dispersed and chemically dispersed oil are a function of the oil type, dispersant type, microbial community structure and environmental factors (such as temperature). It is critical to have an understanding of how the rates are influenced by these variables. Such information is useful during oil spill response efforts and for fate and transport models. The objective of this task is to determine the biodegradation rates of Endicott Crude oil (a potential future EPA reference oil) when physically and chemically dispersed with Corexit.

Task 1.1 Approach: This task is a continuation of EP-C-11-006, WA 3-33 and results shall be used to compare to the findings found in the previous WA. Analytical methods will include measuring markers of Corexit. Monitoring of oil hydrocarbons will be conducted using high-resolution GC/MS/MS instrumentation. Analytes including all alkanes from n-C10 to n-C35 plus pristane and phytane, all resolvable PAHs ranging from 2- to 4-rings and their alkylated homologs, and hopane shall be quantified. In addition, total petroleum hydrocarbons (TPH) shall be quantified by the EPA standard GC/FID method. The NRMRL lab support contractor Team shall modify the existing Category A QAPP, L-15405, to complete the biodegradation work proposed here. The activities under this task are designated as QA category A.

Task 1.1 Deliverables: Outputs shall be in the form of detailed monthly progress reports, submitted in accordance with the contract, describing progress made in the work assignment subtask. A final report shall be prepared by the Contractor summarizing the results from this study and submitted to the EPA WACOR on or before September 29, 2016. Raw data shall be provided to the EPA WACOR in the form of a Microsoft Excel spreadsheet at the conclusion of each dispersant/temperature/oil combination. The format for the data report shall be provided to the Contractor by the EPA WACOR via written technical direction.

TASK 1.2 – Biodegradability of Diluted Bitumen oil by Anderson Ferry and Kalamazoo River Cultures in Freshwater at Two Temperatures.

Task 1.2 Relevance & Objective: The production and shipping of emerging crude oils has increased substantially in the past 5 years. In turn, this causes increased risk to ecosystems and communities for potential spills. One type of emerging crude, bitumen, poses unique problems for spill response and remediation options. This is due to its high viscosity, which requires dilution prior to transport. Dilution with condensate, diluent or synthetic oil produces 'diluted' and 'synthetic' bitumen (dilbit and synbit, respectively). Hence the chemical nature of the bitumen various widely, thus evaluating degradation rates, fate and transport models and toxicity is challenging. Under this WA task, biodegradation rates for 2 types of bitumen, Cold Lake and Western Select. Results will inform transport modeling efforts by NRMRL in Ada, OK for the 2010 bitumen spill in the Kalamazoo River (Jim Weaver, lead). The objective is to evaluate the biodegradability of diluted bitumen by freshwater microbial cultures collected from the Kalamazoo River at two temperatures. The activities under this task are designated as QA category B.

Task 1.2 Approach: This task shall follow the Category B QAPP, L-15405. The contractor shall complete a literature review. As part of this task, *Culture Enrichment* shall be needed, where the EPA WACOR will provide two sources of diluted bitumen. The contractor shall grow two cultures whose only carbon source will be dilbit. A *Parametric Study* on Cold Lake and Western Access diluted bitumen oils will be conducted with the cultures obtained in the enrichment. The contractor shall perform a parametric study on the biodegradation rates achievable with dilbit at 5 and 25 ± 2 °C, and numerous time points sampled. For each sampling event, the hydrocarbon content of each bottle shall be determined in terms of alkanes and aromatics according the EPA Method 8270D Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry.

Task 1.2 Deliverables*:* After completion of the parametric study, the contractor shall prepare at least one manuscript suitable for publishing the results in a peer-reviewed journal. The contractor shall submit all raw data accumulated to date in monthly reports on a spreadsheet file. Samples will also be set aside for future genomic sequencing akin to efforts in Task 1.3 of this WA.

Task 1.3 – Metagenomic Sequencing of Oil Degrading Microbial Communities

Task 1.3 Relevance & Objective: The Office of Research and Development (ORD) is seeking to take advantage of the advances in next generation (NG) sequencing to obtain genetic information for microbial communities relevant to oil degradation. The goal of this research is to better understand biodegradability of oil by differing microbial cultures in deep and surface waters, treated with various dispersants. The overarching goal is to understand if these dispersants and oil dispersed have any significant implications on biodegradation rates. Molecular approaches such as sequencing analysis of phylogenetic genes (e.g., 16S rRNA gene) can provide an idea on the identity of the bacteria inhabiting natural samples. However, these methods provide limited information on the function potential and genetic network of specific microbial populations. To circumvent this, ORD will use NG sequence technologies to better identify the genes associated with different bacterial populations inhabiting enriched/treated mixed cultures. ORD does not currently have the sequencing capabilities required for the completion of this WA task in a timely manner. As a consequence, analytical services are necessary from a laboratory capable of performing the requested sequencing task within the WA PoP, including the use of NG sequencing methods to generate large sequencing databases. The <u>objective</u> of this work assignment task is to conduct next generation sequencing of samples from total microbial community DNA extracted by EPA personnel, and provide sequencing data in electronic form. The EPA WACOR will provide a total of 860 different samples. Additional samples can be provided to replace any sample as needed (i.e., due to QA/QC failure). Samples will include treatments that vary in oil type (light or medium crudes and diluted bitumen), dispersant and culture type (Kalamazoo River, Gulf of Mexico).

Task 1.3 Approach: The contractor shall complete the following tasks in accordance with the requirements set forth below utilizing QAPP (L-15045-QP-1-5, approved December 2013). A revision to this QAPP is requested to ensure that the procedures in that document related to PCR work (SOPs 7 -10, pp. 75-86) described the actual procedures currently used.

Requested work: (1.4a) DNA manipulation- The contractor shall perform any further purification or concentration of the DNA following standard protocols. Additionally, the contractor shall prepare all the index libraries (one index per sample) required for the completion of the work assignment. *(1.4b) Sequencing* - In order to obtain enough information for each sample, there shall be a minimum of 0.4 to 3 GB of sequence information and each library must be sequenced using pair ends of minimum 100-250 bases in length. The contractor shall perform sequencing using a platform that produces single reads of that length. In order to complete these tasks; EPA personnel will perform the DNA extractions using established protocols under the direction of Jorge SantoDomingo in NRMRL. Samples will be concentrated in DNAse-free tubes at desirable amounts and stored frozen at -20°C until processed by the contractor. Each tube will contain a specific sample that will be used in sequencing reactions performed by the contractor. The WACOR will provide written technical direction to the contractor to sequence a specific number of samples.

The contractor shall comply with next-generation sequencing QA/QC requirements as established by the information manufacturer, which will be provided by the EPA WACOR. The contractor shall provide a minimum of 85% of high quality (Phred 20) reads from the total number of reads required, and depending the sample type a length of 100 – 300 bp per each PE run. The contractor shall establish a new, or modify an existing QAAP to accommodate this work. The activities under this task are designated as QA category B.

Task 1.3 Deliverables: The primary output of these tasks will consist of electronic files containing the sequencing results for 16S rRNA genes, metagenomes, and metatranscriptomes. Each sequencing reaction should generate a minimum of 0.4 to 3GB (gigabases) of pair-end reactions. It is expected that the data will be compatible with publicly available sequencing analysis softwares. The contractor shall store the data in a secure site, and provide the data to the WACOR using a file transfer protocol (FTP) approach or via storage devices such as external drives. Due to the amount of sequences per sample that is required in this WA task, the contractor must have high throughput capabilities. It is estimated that a total of 860 samples will be processed as part of this task. The contractor shall provide an average of 0.4 GB sequences per metagenome sample and an average of 2-3 GB sequences per metatranscriptome sample. The WACOR anticipates processing 180 metagenomes and 60 metatranscriptomes. The use of an Illumina HiSeq2500 instrument is known to generate the amount of data required in this WA task. For the metagenomes, the Contractor shall use pair-end (PE)100 and PE150 for the metagenomes and metatranscriptomes, respectively. In addition, the contractor shall provide sequences for phylogenetic genes, i.e., 16S rRNA gene, using a MiSeq instrument and a PE250 approach for approximately 620 samples (in the form of barcoded PCR products). No more than 180 samples should be processed per sequencing run to achieve the desired sequencing depth.

As EPA will perform additional bioinformatic analyses, the contractor shall submit all the raw data files, including FastQ files and contigs as well as other files that are normally produced as next generation sequencing runs are produced. Preferentially, the data will be accessed by the WACOR via internet or sent on an external drive via courier. The contractor shall maintain a backup of this data for the entire duration of the work assignment. The data shall be compatible with sequencing analysis software or similar software. The contractor shall deliver at least 25% of the total analytical services every three months. The activities under this task are designated as QA category B.

TASK 1.4 – Physico-Chemical and Toxicological Characterization of Diluted Bitumen

and Potential EPA Reference Oils (Endicott and Dorado)

Task 1.4 Relevance & Objective: This work assignment task is aligned with task 1.1 and 1.2 on biodegradation, where the same oil types, concentrations and DORs will be used to interrelate to toxicity. Chemical and physical characterization is also needed in order to predict behavior of bitumen in fresh and saltwater environments. The main objective of this work assignment task is to conduct acute and chronic toxicity tests using two types of bitumen, Cold Lake and Western Select. Chemical characterization of the source oils is also a goal.

Task 1.4 Approach: The approved category B QAAP L-21545-QP-1-0, approved July 2015, will need to be modified for task 1.4 of this WA, to include the method development research activities under this task: (1) method development, (2) physico-chemical characterization of bitumen oils and (3) conducting of toxicity studies. *Method development* - A review of the methods currently listed in the Oil Pollution Act Subpart J regulations (recent proposed amendments) for toxicity of NCP products is requested. This will inform the method development for subsequent toxicity tests. Once the method is established via written technical direction from the EPA WACOR during the first 2 months of the WA, toxicity studies shall be conducted by the contractor.

Toxicity - Both fresh and salt water species (fish and invertebrates) shall be evaluated in the toxicity studies. The contractor shall evaluate two types of bitumen oil. The EPA WACOR will acquire one diluted bitumen oil (dilbit) from the Department of Fisheries and Oceans, Canada. The contractor shall use the standard effluent slow stir WAF (Water Accommodating Fraction) for fresh and salt water toxicity tests, with range finder tests conducted to bracket concentration ranges. Chemical analyses (TPH – total petroleum Hydrocarbons) for each test will be required. Six tests per oil, acute for lethality and chronic for sublethal, will be required:

Acute - 48 and 96 hr LC50 (fish) and EC50 (invertebrates); dose response
Species: Mysid; Menidia; Fathead; Daphnid

7 day chronic – NOEC and LOEC ('no' and 'lowest' observed effect concentration)
Species: Mysid; Daphnid

Characterization - This work shall include parameters such as aromatic and alkane composition, specific gravity, viscosity, flammability, pour point. For measuring oil hydrocarbons, the contractor shall adapt the EPA standard GC/MS method to the use of a high-resolution GC/MS/MS instrument conducted on all sacrificial samples with oil. Analytes including all alkanes from n-C10 to n-C35 plus pristane and phytane, all resolvable PAHs ranging from 2- to 4-rings and their alkylated homologs, and hopane shall be quantified. In addition, total petroleum hydrocarbons (TPH) shall be quantified by the EPA standard GC/FID method. The activities under this task are designated as QA category B.

Task 1.4 Deliverables: Outputs shall be in the form of detailed monthly progress reports, submitted in accordance with the contract, describing progress made in the work assignment subtask. A final report shall be prepared by the Contractor summarizing the results from this study and submitted to the EPA WAM on or before September 29, 2016. Raw data shall be provided to the EPA WACOR in the form of a Microsoft Excel spreadsheet at the conclusion of each toxicity test and the physico-chemical characterization.

Section 2-Protocol Development for NCP Oil Spill Countermeasure Products

BACKGROUND

The National Oil and Hazardous Substances Pollution Contingency Plan, or National Contingency Plan (NCP), governs the use of surface washing agents (SWAs), oil dispersants, biological additives, and other chemical agents. Currently the NCP requires submittal of toxicity data for all products listed on the NCP Product Schedule. For dispersants and bioremediation agents, effectiveness data are also required after products have undergone testing in accordance with the published testing protocols developed by the U.S. EPA. EPA developed the Baffled Flask Test (BFT) and the Bioremediation Agent Test as standardized measures of effectiveness for these agents. Currently protocols for evaluating the effectiveness of SWAs and solidifiers have not been developed. Having such protocols would aid on-scene coordinators in making informed decisions and enhance the likelihood of a successful clean-up operation. Section 2 of this work assignment contains four sections dedicated to protocol development.

2.1 - Complete Development of a Surface Washing Agent Protocol

Task 2.1 Relevance & Objective: Surface washing agents (SWAs), also known as shoreline cleaning agents, can be used following an oil spill event to enhance the removal of stranded oil from shoreline surfaces. SWAs are designed to facilitate the release of stranded oil from substrate surfaces and subsequently transfer that oil to near-shore receiving waters. In biologically sensitive areas, cleaning agents should not disperse the oil into the receiving waters or promote oil penetration into permeable shoreline matrices. Once released, the oil should re-coalesce to form a slick that can be recovered through physical containment and mechanical skimming operations. The use of SWAs as a remediation tool is generally recommended when conventional methods cannot be used on shorelines (including mechanical removal technologies, such as high-pressure water washing, hot-water washing, steam cleaning, and physical removal of beach substrate). These conventional techniques are often invasive, impractical, or detrimental to the natural species within the impacted environment. The objective of task 2.1 of this work assignment (WA) is to develop a standardized and reproducible testing protocol to evaluate the cleaning efficiency of SWAs via conducting reproducibility studies of SWA experiments. The activities under this task are designated as QA category A.

Task 2.1 Approach: The contractor shall complete this task utilizing QAPP (L14866) and the

SWA QAPP (L10539-QP-1-5).

Oil removal efficiencies for SWA treatments shall be compared to the washing efficiency of water without SWA. Since a good SWA should not disperse oil into water, the dispersability of each SWA will be evaluated separately using the Baffled Flask Test (BFT). Protocol experiments shall be conducted using Prudhoe Bay Crude (PBC), a medium crude oil. Additionally, a subset of experiments will be conducted using two potential new EPA reference oils that will be established in FY16 dependent on selection by Office of Emergency Management. The EPA WACOR will specify the two oils via written technical direction, and will provide them to the contractor, who will continue research by conducting SWA experiments. The contractor shall use sand and gravel inside metal wire baskets to test the ability of SWAs to remove oil adhered to the surface. Oils will be added in a gridded droplet formation to sand or gravel within the baskets. After a weathering time (approx. 18 hours), SWA will be added to oil droplets with varying SOR (SWA to Oil Ratio), SWA dilution, contact time, water rinse volume and drain time. Testing will be conducted on at least 15 commercial SWA products that EPA has in its possession. The water and washed oil will be collected in a beaker, and the amount collected will be extracted in dichloromethane (DCM) and measured by the spectrophotometric method (at three different wavelengths, 340, 370, and 400 nm) used in the previous work assignments under EPC11006 (WA 0-5, WA 1-05, WA 3-05).

The contractor shall extract the amount of oil remaining on the sand grains or gravel separately and measure in the same manner. A mass balance should result when the amount of oil still embedded in the sand or gravel is summed with the amount washed into the receiving beaker. The contractor shall perform the above experiment in a factorial manner in replicate. The variables are SWA, oil types, oil drip-drying time, exposure time to SWA, and washing time. Temperature will at room temperature. Controls that receive no SWA, just water, shall also be analyzed. Water will be the artificial seawater (GP2) formulation. For additional information on experimental parameters, refer to the dissertation by Dr. Karen Koran, University of Cincinnati. The activities under this task are designated as QA category A.

2.2 – Dispersant Effectiveness using the BFT Dispersant Protocol

Task 2.2 Relevance & Objective: The use of dispersants is typically limited to open sea situations, where dispersion of the oil into the water column shifts the environmental impact of a spill from ocean surface to the water column. The addition of dispersants allows for the formation of smaller oil droplets which can be respired by microbial populations. The objective of this WA task is to conduct a series of Baffle Flask Tests (BFT) using a variety of crude oils including potential EPA reference oils, Endicott and Dorado. Testing will also include investigations over a range of salinities from 0 (freshwater) to up to 90 PSU (hypersaline waters) for a more comprehensive look at the effect of salinity on dispersant effectiveness (DE). In addition to UV-VIS detection typically used, fluorescence techniques will be investigated to determine their appropriateness in determining DE.

Task 2.2 Approach: The contractor shall complete the following task utilizing an approved QAPP; QA ID L14866-QP-1-6. This QAPP will be modified for inclusion of a wider salinity range and fluorescence methods. This WA builds upon previous efforts under EPC11006 (WA 03_05 and 04-05) that evaluated the mixing energy in the BFT when operated at 250 rpm and with 180 ml of seawater in the flask. In the older BFT, the mixing energy was determined at 200 rpm and 120 ml volume. Under EPC11006 WA3-05 and 04_05 , the contractor conducted the BFT at both mixing speeds (180 and 250 rpm) and volumes (120 and 180 ml) on a rotary shaker in a constant temperature room at 25 °C± 2 °C and 5 ± 0.5 °C using the two new reference oils. Replicates were tested to determine the pass-fail decision criteria at each of the testing conditions. Corexit 9500 and finasol were used to establish the pass-fail rules at different dispersant-to-oil ratios (DORs; 1:25, 1:50, 1:100 and 1:200). In this new WA 0-05, the contractor shall work under this effort to obtain results that will assist in final determination of the pass-fail criteria. The activities under this task are designated as QA category A.

2.3 – Complete Development of Solidifier Protocol

Task 2.3 Relevance & Objective: Solidifiers are products composed of dry high molecular weight polymers that have a porous matrix and large oleophilic surface area. Solidifiers form a physical bond with the oil. When applied to spilled oil, the oil viscosity increases to the point that it becomes solidified into a rubberlike solid. The end product can range from a firm cohesive mass to a noncohesive granular material. Solidifiers are available in various forms, including dry powder, granules, semisolid materials (e.g., pucks, cakes, balls, sponge designs), and contained in booms, pillows, pads, and socks. Solidifier products are listed on the NCP Product schedule, but currently no universal protocol for testing their effectiveness exists. The objective of this work assignment task is to develop and conduct a round robin experiment to evaluate solidifier efficacy protocol proposed in under EPC11006; QAPP ID L11068.

Task 2.3 Approach: The contractor shall develop a revised QAPP using the existing QA ID -L-10197-QP-1-8, approved July 2015. This work is a continuation of the parametric study of solidifier efficacy conducted in WA 03-23. Previously, two oils were exposed to 10 solidifiers at 2 temperatures (25 °C± 2 °C and 5 ± 0.5 °C) and 1 SOR (1:2). The six replicates were conducted at fixed mixing speed (60 rpm) and water type (fresh water). In section 2.3 of this WA 0-05, a round robin experiment shall be developed and conducted to test the robustness of this method. The contractor shall evaluate the effects of operator, SOR, temperature and solidifier type on effectiveness. The activities under this task are designated as QA category A.

2.4 – Testing of Bioremediation Products using NCP Bioremediation Agent Protocol

Task 2.4 Relevance & Objective: Just like dispersants, solidifiers and surface washing agents, bioremediation products are listed on the National Contingency Plan Product Schedule. However, bioremediation agents and dispersants are the only categories that currently require effectiveness testing. The objective of this WA task is to begin evaluating the current effectiveness test for possible modifications for improvement. A portion of this task will be literature review of the existing test and data that is publicly available, followed by limited laboratory analysis of the test on crude oils available in the EPA lab facility.

Task 2.4 Approach: The contractor shall develop a new Category A QAPP to cover the existing bioremediation testing for listing on the National Contingency Plan Product Schedule. The Contractor shall evaluate the pass-fail criteria of bioremediation agents in planning for exploratory experiments to evaluate the existing testing protocol on the NCP Product Schedule. The activities under this task are designated as QA category A.

Overarching TASK 2 DELIVERABLES

The contractor shall provide raw data to the EPA WACOR in the form of a spreadsheet for each monthly report and at the completion of Task 2. These spreadsheets will contain the raw data from the surface washing agent, dispersant and solidifier sub tasks. At the end of the WA period of performance, the contractor shall submit a report to the EPA WACOR for use toward a publication in a peer-reviewed journal.

To: Mike Fulton - NOAA Federal[mike.fulton@noaa.gov]
From: Conmy, Robyn
Sent: Tue 5/17/2016 4:19:59 PM
Subject: RE: purchase of finasol and corexit

I saw this. Thanks for checking in with us!

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Mike Fulton - NOAA Federal [mailto:mike.fulton@noaa.gov]
Sent: Tuesday, May 17, 2016 11:32 AM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: Re: purchase fo finasol and corexit

Hi Robyn,

Have you heard that samples from DWH are going to be released? I believe they have Corexit 9500.

Mike

On Tue, Apr 12, 2016 at 12:59 PM, Mike Fulton - NOAA Federal <mike.fulton@noaa.gov>

wrote:

Good luck. You may have more leverage than we did. At one point, I thought we were very close to getting some, but their attorneys changed their mind.

On Tue, Apr 12, 2016 at 8:56 AM, Conmy, Robyn <Conmy.Robyn@epa.gov> wrote:

Thanks Mike. This is our same contact, so I guess I will just keep trying to reach her. EPA is looking to procure a few gallons and will be doing toxicity testing. We will ask nicely and point out that the testing will be used to help with finalizing the NCP Subpart J language. If they still won't sell, we will look into if there is regulatory language that exists to help convince them to waive the waiver requirements. As you know, access to Nalco dispersants is quite a challenge for research.

Cheers,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Mike Fulton - NOAA Federal [mailto:mike.fulton@noaa.gov]
Sent: Tuesday, April 12, 2016 8:41 AM

To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: Re: purchase fo finasol and corexit

Hi Robyn,

See below contact info for NALCO. You may have more success if you can sign a waiver that you won't use for toxicity testing. Good luck.

Mike

Debby.Theriot@nalco.com

281 263 7709

On Tue, Apr 12, 2016 at 7:58 AM, Conmy, Robyn <Conmy.Robyn@epa.gov> wrote:

Thanks Mike. I spoke to a contact at Total yesterday and we are getting some Finasol. Nalco hasn't responded to a voicemail as of yet, so your contact at Nalco could be a huge help.

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Mike Fulton - NOAA Federal [mailto:mike.fulton@noaa.gov]
Sent: Monday, April 11, 2016 5:00 PM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: Re: purchase fo finasol and corexit

Hi Robyn, Ultimately, We weren't able to get Corexit from Nalco, but I'll get you the contact info for both manufacturers.

On Monday, April 11, 2016, Conmy, Robyn <Conmy.Robyn@epa.gov> wrote:

Hi Mike,

Awhile back we had discussed NOAA's possible procurement of Corexit and Finasol for your toxicity work. Would you mind sharing the POC for Nalco and Total that were contacted in your hunt to procure the dispersants?

Thanks,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

--

Dr. Michael H. Fulton-Estuaries and Land Use Branch Chief

Center for Coastal Environmental Health and

Biomolecular Research (CCEHBR)

USDOC/NOAA/NOS/NCCOS

219 Fort Johnson Road

Charleston, SC 29412-9110

voice: (843) 762-8576 fax: (843) 762-8700

e-mail: mike.fulton@noaa.gov

--

Dr. Michael H. Fulton-Estuaries and Land Use Branch Chief

Center for Coastal Environmental Health and

Biomolecular Research (CCEHBR)

USDOC/NOAA/NOS/NCCOS

219 Fort Johnson Road

Charleston, SC 29412-9110

voice: (843) 762-8576 fax: (843) 762-8700

e-mail: mike.fulton@noaa.gov

--

Dr. Michael H. Fulton-Estuaries and Land Use Branch Chief

Center for Coastal Environmental Health and

Biomolecular Research (CCEHBR)

USDOC/NOAA/NOS/NCCOS

219 Fort Johnson Road

Charleston, SC 29412-9110

voice: (843) 762-8576 fax: (843) 762-8700

e-mail: mike.fulton@noaa.gov

--

Dr. Michael H. Fulton-Estuaries and Land Use Branch Chief

Center for Coastal Environmental Health and

Biomolecular Research (CCEHBR)

USDOC/NOAA/NOS/NCCOS

219 Fort Johnson Road

Charleston, SC 29412-9110

voice: (843) 762-8576 fax: (843) 762-8700

e-mail: mike.fulton@noaa.gov

To: Berolzheimer, Benjamin[Berolzheimer.Benjamin@epa.gov]; Sjogren, Mya[Sjogren.Mya@epa.gov]; Richardson, Teri[Richardson.Teri@epa.gov]
From: Conmy, Robyn
Sent: Fri 10/14/2016 2:01:06 PM
Subject: SHC 3.62 BOSC oil posters
BOSC 3_62 Task 1 poster_conmy.pptx
BOSC 3_62 Task 2 poster_conmy.pptx
BOSC 3_62 hot topic poster_conmy.pptx

Attached are the 3 cleared posters for printing.

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

Actionable Science for Communities

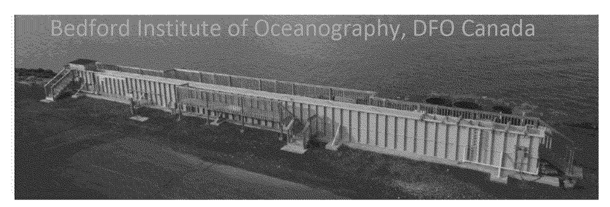
SHC 3.62.1 Wave Tank Oil Plume Simulations

Robyn Conmy, NRMRL

EPA United States Environmental Protection Agency

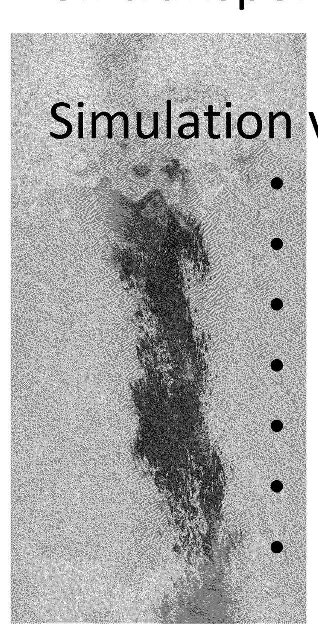
Purpose/Utility of Research

Oil plume dispersion simulation experiments have been conducted over the past 5 years in collaboration with the Canadian Government within the large- scale wave tank at the Bedford Institute of Oceanography.



This research is critical for advancing science with respect to aspects of spill preparedness, response, and remediation; particularly during Spills of National Significance.

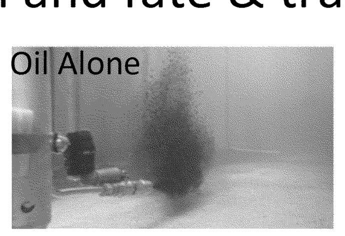
Optical sensors are used during oil spill response to determine oil presence in slicks and plumes. *In situ* sensors were deployed during the Deepwater Horizon (DWH) oil spill to track shallow and deep subsea plumes. Tank simulations address knowledge gaps in uncertainties regarding sensor capabilities, plume formation, droplet size distribution (DSD), dispersion effectiveness, and oil transport.

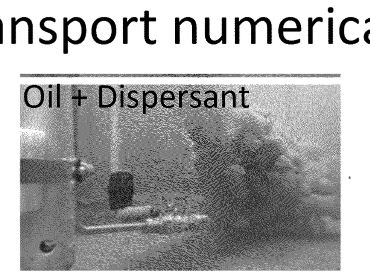


Simulation variables include:

- Oil release type
- Oil temperature (reservoir temp ~ 80 °C)
- Water temperature (5 °C - 22 °C)
- Oil type (ANS, SLC, IFO-120)
- Dispersant (Corexit 9500; Finasol OSR52)
- Dispersant to oil ratio (DOR)
- Salinity (20-100 ppt)

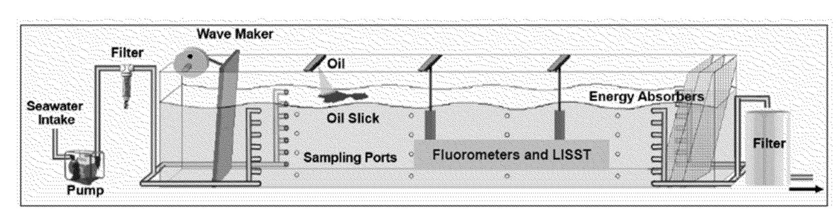
Results offer information on the behavior and dispersibility of oils, with implications for droplet formation and fate & transport numerical models.

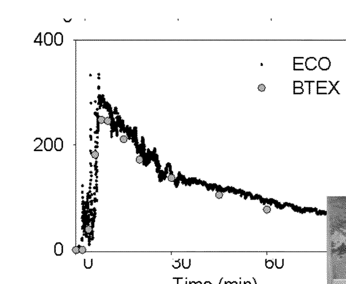


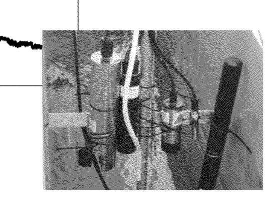


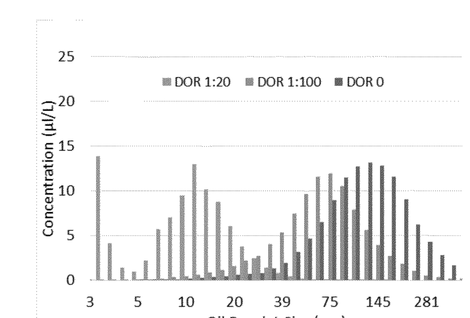
Highlights

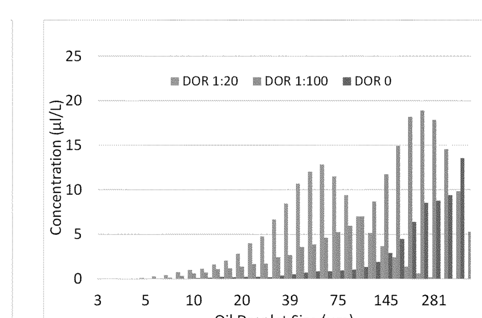
- Simulation experiments provide for evaluating factors that influence oil dispersion and how forensic field sensors detect dispersed oils.
- Evaluation of *in situ* fluorometers used during the *Deepwater Horizon* oil spill demonstrated a detection of 300 ppb oil, refuting previous misconceptions of 1 ppm oil detection limit.
- Simulation research is critical for the Agency's spill preparedness and response efforts.
- Jet simulations inform SSDU (Sub-Surface Dispersant Use) planning by EPA OLEM, which coincides with the API (American Petroleum Institute) efforts.
- On-going simulations include dispersion under hypersaline water conditions for Arctic and deep spill preparedness.











Application & Translation

40 CFR Decision-rule Amendments

Performance evaluation of sensors via a novel approach for sensor assessment, calibration, and appropriateness was published in Conmy *et al.,* 2014 (ES&T). This manuscript serves as a citation within the Federal Register proposed decision- rule amendments to the 40 CFR § 300.900-920 subpart J for spill monitoring requirements.

Expert Witness Deposition

Conmy *et al.,* 2014 was also used by the Department of Justice as material during depositions for the DWH Clean Water Act Penalties trial.

EPA 600/R-16/152 Federal Report

A recent report summarized the high-pressure jet oil releases simulations for evaluating droplet fractionation and tuning the oil droplet formation numerical model, JETLAG used during DWH.

Scaling Up

BIO wave tank simulations have now translated to work at the larger OHMSETT facility.

Intended End users

- EPA Office of Land and Emergency Management
- National and Regional Response Teams
- Federal On-Scene Coordinators
- Oil spill emergency responders

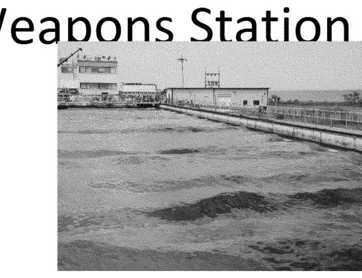
Research products are used to:

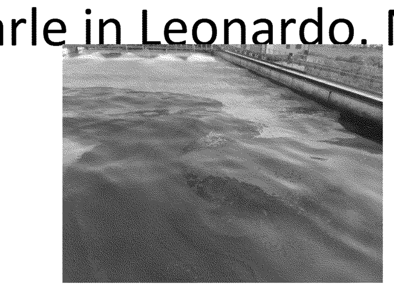
1) Improve response monitoring guidance
2) Assist with Area Contingency Plans
3) Enhance spill preparedness
4) Serve as citations in 40 CFR decision rules

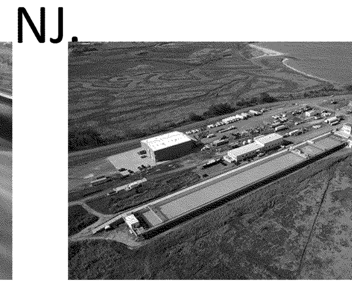
Lessons Learned

In US waters, intentional releases of oil are not permissible. For research purposes, permits are difficult to obtain and time- prohibited. Thus, oil dispersion simulation large- scale wave tanks are vital to advancing the science forward. This type of research has a large return on investment for the EPA and the oil spill community.

Research findings have translated to larger scale experiments at the US operated OHMSETT facility at Weapons Station Earle in Leonardo, NJ.







EPA initiated and executed Interagency Agreements (funds in to EPA) with Department of Interior's Bureau of Safety and Environmental Enforcement and the Department of Fisheries and Oceans Canada to conduct jet release research. Sensor calibration research was funded through NOAA.

United States Environmental Protection Agency

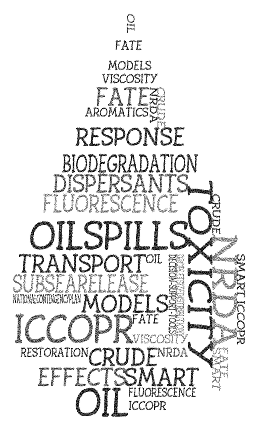
Actionable Science for Communities

Behavior, Fate and Effects of Oil and Spill Agents SHC Task 3.62.1

Robyn Conmy, Task Lead, NRMRL
Jim Weaver, Deputy Task Lead, NRMRL

Problem Summary & Decision Context

EPA is responsible for assessing environmental releases of oils and fuels.

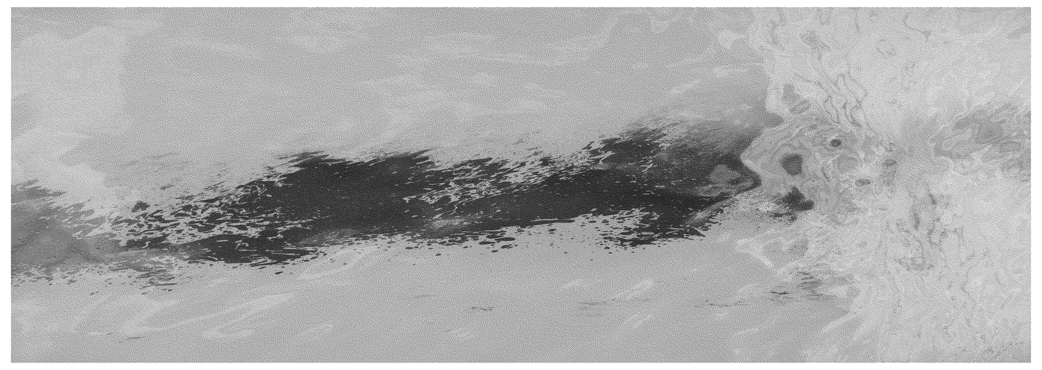


Releases can potentially affect human health and the environment though their impacts on water quality, or through direct exposure to toxic constituents.

SHC 3.62.1 research addresses the overarching question:

What management, response an remediation actions are effective for minimizing environmental and human consequences resulting from oil spills?

Research products provide guidance for OLEM and Regions regarding spill preparedness, response and remediation efforts



Task Overview

- This task is dedicated to research on the biodegradation, weathering, dispersion, toxicity and behavior of oil and spill agents in support of the EPA Office of Land and Emergency Management (OLEM) and the Regions.
- Research efforts improve the understanding of oil fate & transport; establish appropriate response, remediation and restoration methods; and enhance spill preparedness by determining potential impacts of mitigation technologies to communities and ecosystems
- Ecological and human health impacts associated with spilled oil and mitigation technologies (e.g. dispersants) are of concern for or impacted communities.
- Awareness by emergency responders and scientists has been heightened on the capabilities and limitations of spill response methods in use today, particularly for atypical spills (deep-water, high pressure, jet release, prolonged, under-the-ice spills).
- Unconventional oils (diluted and synthetic bitumen from oil sands formations) are particularly difficult to remediate and exhibit chemical and physical behavior, requiring better characterization of these oils.

Accomplishments

Deepwater Horizon Field Sensor Evaluation

- A novel approach for evaluating *Deepwater Horizon (DWH)* oil spill field sensors was developed using wave tank oil plume simulations. Conmy *et al.*, 2014 is a citation within the 40 CFR § 300.900-920 proposed decision-rule and was used as testimony material during the DWH trial.

Wave tank Oil Plume Simulations

- ORD has completed an EPA 600 series report (Conmy *et al.*, 2016) for Interagency Agreement research with Dept. of Interior and the Canadian government to conduct high- pressure jet release simulations for various oil type, dispersant concentrations, and water temperature.

Oil Biodegradation

- SHC 3.62 conducts various oil and spill agent biodegradation experiments. Recent publications include Deshpande *et al.*, 2017 (in prep); Zhuang *et al.*, 2016; Campo-Moreno *et al.*, 2013

.

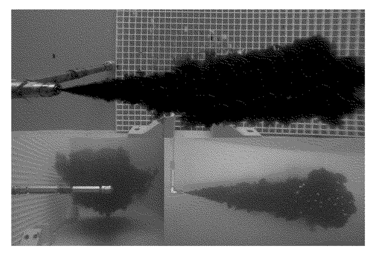
Spill Response Oil Mapping

- Collaborative perspective journal article on DWH technologies White *et al.*, 2016.

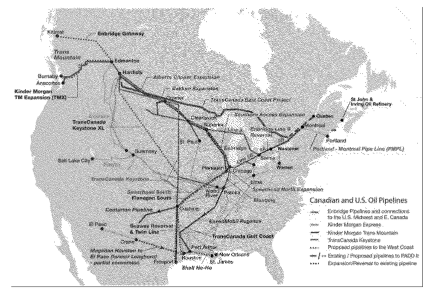
Future Directions

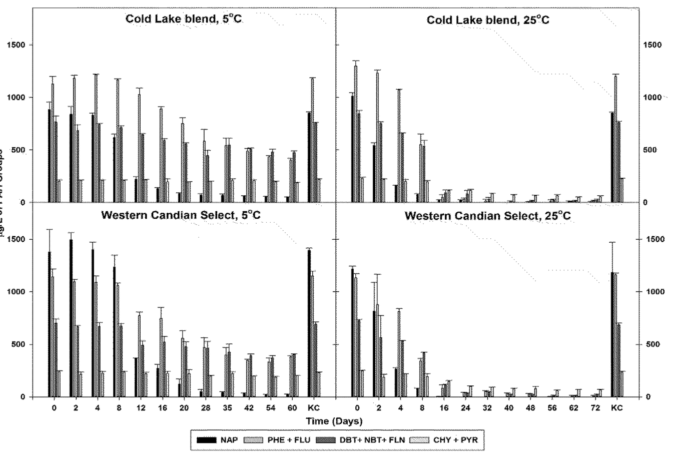
SHC 3.62 has planned for the following deliverables under Task 1 in support of OLEM and the Regions:

- Conduct oil dispersion experiments at the DFO Canada wave tank facility to evaluate the influence of hypersaline waters on plume formation. Report due to the Department of Interior in FY17.

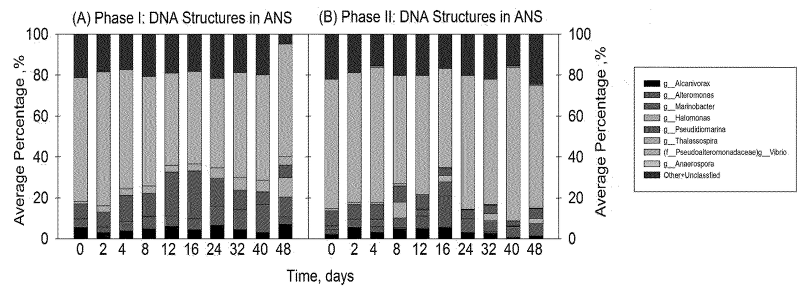


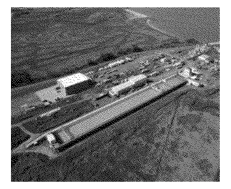
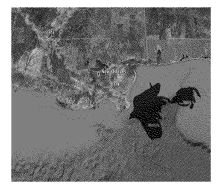
- Continue with biodegradation and toxicity of diluted bitumen experiments. A summary report is due to OLEM program office in FY17, with a manuscript in prep (Deshpande *et al.,* 2016).

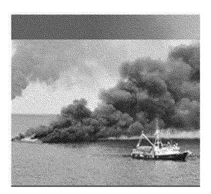
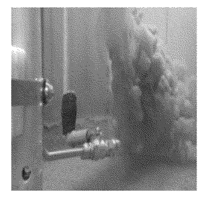




- Complete the biodegradation and metagenomic analyses of Alaskan crude oils exposed to two dispersants. This research highlights how biodegradation rates vary as a function of microbial consortia. This has critical implications for understanding fate and transport of oil. Two manuscripts are in prep: Zhang *et al.*, 2017 and SantoDomingo *et al.*, 2017).



Actionable Science for Communities

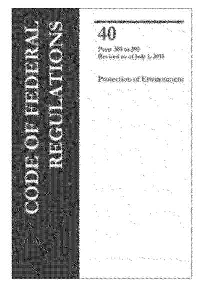
United States Environmental Protection Agency

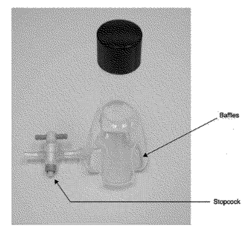
National Contingency Plan Protocol Development SHC Task 3.62.2

Robyn Conmy, Task Lead, NRMRL
Jim Weaver, Deputy Task Lead, NRMRL

Problem Summary & Decision Context

US EPA has regulatory authority of over the National Oil and Hazardous Substances Product Schedule (NCPPS) for listing products for treating oil spills.





ORD develops effectiveness and toxicity protocols in support of the NCPPS.

Protocols provide guidance to emergency responders and contingency planners regarding the effectiveness and suitability of specific products during spills.

Such information assists with decision-making and evaluating tradeoffs for potentially impacted communities and ecosystems.

Public listing of a product's efficacy and toxicity also drives the private sector to continue to advance remediation and response technologies for various conditions and oil products.

Task Overview

- Mandated by the Oil Pollution Act (OPA 90) and the National Oil and Hazardous Substances Contingency Plan (NCP), EPA is responsible for maintaining the NCP Product Schedule (NCPPS) for listing spill countermeasure products.
- Efficacy and toxicity protocols for these products (dispersants, solidifiers, surface washing agents, bioremediation agents) are developed by SHC 3.62.2.
- SHC 3.62.2 research products are dedicated to protocol development in support of the EPA Office of Land and Emergency Management (OLEM) and the Federal Register 40 CFR § 300.900-920 Subpart J.
- Products enhance preparedness efforts by the Regions to protect communities from exposures to environmental releases of oils and fuels.

Accomplishments

Dispersant Effectiveness Baffled Flask Test

- SHC 3.62 researchers developed a dispersant efficacy test for the NCPPS. Publications form this work; Venosa *et al.*, 2002 and Holder *et al.*, 2015 are citations within the proposed decision-rule for the 40 CFR § 300.900-920.

Solidifier Effectiveness Test Development

- SHC 3.62 researchers are developing a protocol for solidifier products in support of the NCP. Initial evaluation of the protocol was published in Sundaravadivelu *et al.*, 2016.

Surface Washing Agent Effectiveness Test Development

- SHC 3.62 researchers are developing a protocol for SWA / shoreline cleaner products in support of the NCP. Initial evaluation of the protocol was presented as an internal report to OLEM in 2015 with reproducibility study underway.

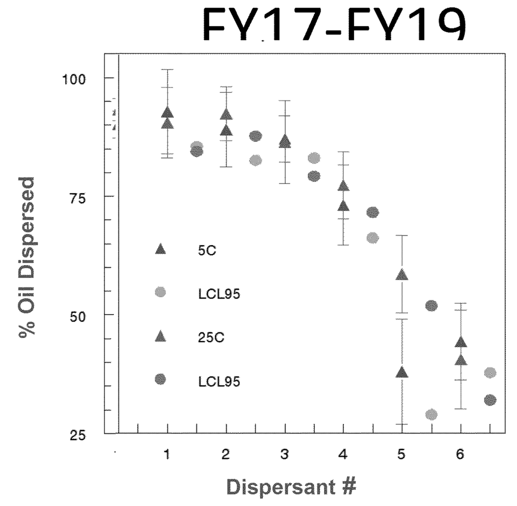
Dissemination of Research Findings

- Research updates presented at ICCOPR (Interagency Coordinating Committee for Oil Pollution Research) and NRT (National Response Teams) S&T quarterly meetings to share findings with Regions, Program Office partners, other spill response federal agencies and NGOs.

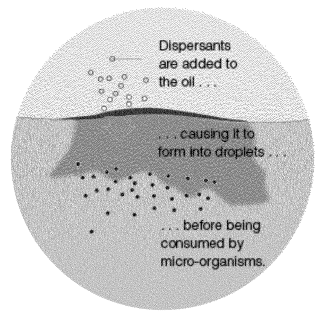
Future Directions

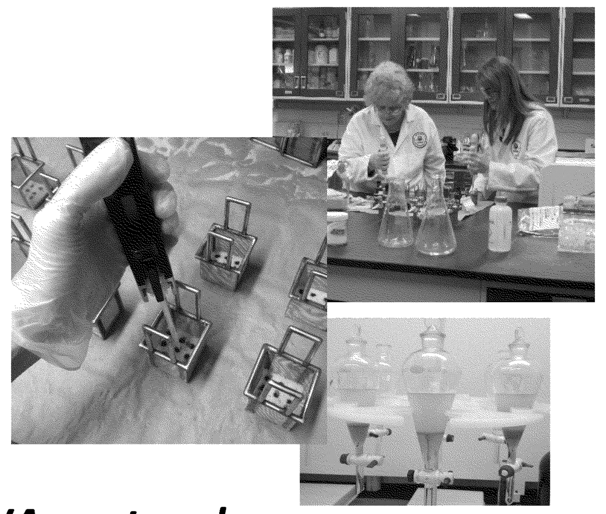
SHC 3.62 has planned for the following deliverables under Task 2 in support of OLEM, the Regions and the NCP:

- Completion of a Surface Washing Agent effectiveness Protocol. Repeatability and Reproducibility studies are underway for the draft protocol. Final Report using existing EPA reference oils is due to OLEM in FY18.
- Completion of a Solidifier effectiveness Protocol. A Round Robin experiment of the draft protocol is underway. Final Report using existing EPA reference oils is due to OLEM in FY19.
- Selection of new EPA Reference Oils for the NCPPS. Currently, stockpiles of the 2 existing EPA reference oils for product testing are dwindling. SHC 3.62 is working with OLEM to screen for new oils. Chemical characterization, performance evaluation and toxicity screening for the light/medium category is near complete. OLEM has yet to procure the heavy oil for testing. Deliverable for oil selection scheduled between FY17-FY19



Dispersant effectiveness BFT results for 6 products





SWA protocol development

To: Mike Fulton - NOAA Federal[mike.fulton@noaa.gov]
From: Conmy, Robyn
Sent: Tue 4/12/2016 11:58:49 AM
Subject: RE: purchase fo finasol and corexit

Thanks Mike. I spoke to a contact at Total yesterday and we are getting some Finasol. Nalco hasn't responded to a voicemail as of yet, so your contact at Nalco could be a huge help.

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Mike Fulton - NOAA Federal [mailto:mike.fulton@noaa.gov]
Sent: Monday, April 11, 2016 5:00 PM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: Re: purchase fo finasol and corexit

Hi Robyn, Ultimately, We weren't able to get Corexit from Nalco, but I'll get you the contact info for both manufacturers.

On Monday, April 11, 2016, Conmy, Robyn <Conmy.Robyn@epa.gov> wrote:

Hi Mike,

Awhile back we had discussed NOAA's possible procurement of Corexit and Finasol for your toxicity work. Would you mind sharing the POC for Nalco and Total that were contacted in your hunt to procure the dispersants?

Thanks,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

--

Dr. Michael H. Fulton-Estuaries and Land Use Branch Chief

Center for Coastal Environmental Health and

Biomolecular Research (CCEHBR)

USDOC/NOAA/NOS/NCCOS

219 Fort Johnson Road

Charleston, SC 29412-9110

voice: (843) 762-8576 fax: (843) 762-8700

e-mail: mike.fulton@noaa.gov

To: Robyn Conmy[conmy.robyn@gmail.com]
From: Conmy, Robyn
Sent: Wed 1/20/2016 5:46:22 PM
Subject: FW: State-of-Science Arctic Dispersants: Degradation & Fate group - REPLY REQUESTED
2015.12.22_Degradation and Fate.docx

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Mandsager, Kathy [mailto:kathy.mandsager@unh.edu]
Sent: Wednesday, December 23, 2015 11:00 AM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>; fingasmerv@shaw.ca; tchazen@utk.edu; robert.jones@noaa.gov; mandyjoye@gmail.com; ken.lee@csiro.au; tracee.nguyen@csiro.au; mbleigh@alaska.edu; karl.linden@colorado.edu; kmmcfarlin@alaska.edu; msmiles@lsu.edu; thomas.s.coolbaugh@exxonmobil.com; mathijs.smit@shell.com; Sprenger, Mark <Sprenger.Mark@epa.gov>
Cc: Gary Shigenaka - NOAA Federal <gary.shigenaka@noaa.gov>; doug.helton@noaa.gov; Principe, Vanessa <Principe.Vanessa@epa.gov>; Wilson, Gregory <Wilson.Gregory@epa.gov>; nancy.kinner@unh.edu
Subject: State-of-Science Arctic Dispersants: Degradation & Fate group - REPLY REQUESTED

Dear Colleagues in the Degradation & Fate group, Thank you for participating in our recent call (on 12/16). Attached is the latest draft of our document for your perusal. Please review the comments that still need to be discussed and/or edited.

In order to select our next WebEx meeting as soon as possible (in January), please use this doodle poll>> http://doodle.com/poll/vdivwmyha6ma6593 by Monday 1/4 so that a date can be selected. It is time-zone enabled for your convenience.

Wishing you all a wonderful holiday season and we look forward to continuing our work in the New Year!

Kathy Mandsager

Program Coordinator

Coastal Response Research Center

Center for Spills and Environmental Hazards

234 Gregg Hall, Colovos Rd

University of New Hampshire

Durham, NH 03824

603.862.1545

To: Robinson, Brian[Brian.Robinson@dfo-mpo.gc.ca]; King, Thomas L[Tom.King@dfo-mpo.gc.ca]
From: Conmy, Robyn
Sent: Mon 5/11/2015 6:26:15 PM
Subject: RE: subsea release experiments

Let's plan for a call on Wednesday afternoon. You call me? 1:00 your time?

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Robinson, Brian [mailto:Brian.Robinson@dfo-mpo.gc.ca]
Sent: Thursday, May 07, 2015 2:47 PM
To: Conmy, Robyn; King, Thomas L
Subject: RE: subsea release experiments

Hi Robyn,

I was just about to send you a message about the status of the fluorometers. That is great if we will get them next week. We just opened the wave tank facility last week, and everything appears to have survived our harsh winter. We are currently running a few dilbit experiments, which will free up some time to start our subsurface injection experiments in the coming weeks. To answer your questions:

1) **VOC Paper** –I'm still working on it…I had to put it aside for a few weeks while I finished another paper based on our work the Chinese SOA. Since I hate being the hold up in getting this work out in press, next week I will send all of the data that I have prepared so far and perhaps together we can work on finishing the paper.

2) **Shimadzu** - I've been working with Mary to get the QS shipped to us. If all goes well she will be sending it out on May 11th. Once it arrives, I will have Claire prepare the solutions and run them.

3) **Start Date** - Once we have the fluorometers, we can start pretty much any time. We plan to conduct all the additional experiments, including 9 runs with Finasol and ANS, and 6 runs with MC252 and Corexit. I'm also working with Michel to co-ordinate his visit here to conduct his jet characterization measurements.

4) **Live Oil** - Unfortunately generating live oil is a much more complex process than we thought, and would require purchasing new equipment (http://goo.gl/Cwo5bU) and likely hiring someone with expertise in performing this type of work. In the no-cost BSEE extension we proposed injecting two types of gases into the tank. After speaking with Michel, he felt as though injecting a gas would produce little data of value. Therefore, instead we are proposing a series of experiments using a sample of gas condensate.

A conference call next week would be a great idea. We are free next Wed, Thursday afternoon, or Friday. Please let us know what date and time works best for you. I think Rod may join us as well since he has a few questions regarding the new BSEE proposal. I'll also see if Michel can call in.

Thanks,

Brian

From: Conmy, Robyn [mailto:Conmy.Robyn@epa.gov]
Sent: May 7, 2015 1:00 PM
To: Robinson, Brian; King, Thomas L
Subject: subsea release experiments

Hi Brian and Tom,

I have shipped the fluorometers back to you. They should arrive by Wednesday next week. If they do not, please email me and I will track them down.

In an effort to get us back on track with this project, here are some items / questions that I have:

1. What is the status of the VOC in air data and manuscript that Brian is working on? The EPA program office is eager to see what was found during the experiments?

2. How is the Shimadzu EEMS fluorometer looking? Do you have the quinine sulfate from Mary?

3. What is the start date for Spring experiments? And are a few runs with South LA crude still planned?

4. How is the preparation coming along for live oil release?

Keep in mind that our draft report to BSEE is due in August. I may plan for a trip to BIO in the beginning of July, if that works for your schedule. This way we can pull together all the data for the report.

Maybe a call for early next week would be a good idea?

Cheers,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

To: Robyn Conmy[conmy.robyn@gmail.com]
From: Conmy, Robyn
Sent: Tue 7/19/2016 7:38:04 PM
Subject: FW: ICCOPR Presentations (Reduced Size PDF)
ICCOPR FY16 Qtr3 Meeting Presentations1.pdf

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>
Robyn N. Conmy, Ph.D.
Research Ecologist
USEPA/NRMRL/LRPCD
26 West MLK Drive
Cincinnati, Ohio 45268
513-569-7090 (office)
513-431-1970 (EPA mobile)
727-692-5333 (Personal mobile)
conmy.robyn@epa.gov

-----Original Message-----
From: Brooks, Rebecca J LT [mailto:Rebecca.J.Brooks@uscg.mil]
Sent: Friday, July 08, 2016 10:05 AM
To: Loring, Joseph B CAPT <Joseph.B.Loring@uscg.mil>; Weaver, James (USCG) <James.D.Weaver@uscg.mil>; Scott.A.Stoermer@uscg.mil; Ottenwaelder, Thomas A CDR <Thomas.A.Ottenwaelder@uscg.mil>; Sligh, Kevin M CIV <Kevin.M.Sligh@uscg.mil>; Carnegie, Tammie R LT <Tammie.R.Carnegie@uscg.mil>; Crecy, Stacey L LCDR <Stacey.L.Crecy@uscg.mil>; Platt, Jeffrey R LCDR <Jeffrey.R.Platt@uscg.mil>; Brooks, Rebecca J LT <Rebecca.J.Brooks@uscg.mil>; Maghini, Monica K CIV <Monica.K.Maghini@uscg.mil>; Hall, Gregory CDR (EDU) <Gregory.Hall@USCGA.EDU>; Fletcher, James E CIV <James.E.Fletcher@uscg.mil>; kurt.a.hansen@uscg.mil; Balsley, Alexander CIV <Alexander.Balsley@uscg.mil>; DiRenzo, Joseph CIV <Joseph.DiRenzo@uscg.mil>; mark.g.vanhaverbeke@uscg.mil; Catanach, Curtis P CIV <Curtis.P.Catanach@uscg.mil>; Chaves, Wendy <Wendy.G.Chaves@uscg.mil>; Jenkins, Shannon R CIV <Shannon.R.Jenkins@uscg.mil>; dave.westerholm@noaa.gov; scott.lundgren@noaa.gov; steve.lehmann@noaa.gov; john.kucklick@nist.gov; jason.boehm@nist.gov; Elena.Melchert@hq.doe.gov; Erica.Folio@Hq.Doe.Gov; kevin.easley@hq.doe.gov; david.moore@bsee.gov; Lori.Medley@bsee.gov; william.vocke@bsee.gov; joseph.levine@bsee.gov; Walter.Johnson@boem.gov; brian.zelenke@boem.gov; Jeff.Ji@boem.gov; barry_Forsythe@fws.gov; holly_herod@fws.gov; christina_kravitz@fws.gov; michael.carter@dot.gov; tom.thompson@dot.gov; robert.w.smith@dot.gov; james.merritt@dot.gov; David.Lehman@dot.gov; Steven.V.Cary@usace.army.mil; Andrew.J.Bruzewicz@usace.army.mil; Nathan.J.Lamie@usace.army.mil; Kemp.skudin@navy.mil; frank.stone@navy.mil; abe.nachabe@navy.mil; michael.s.dean@navy.mil; daniel.eldredge@navy.mil; Stephanie A. Brown <stephanie.a.brown@navy.mil>; Conmy, Robyn <Conmy.Robyn@epa.gov>; Principe, Vanessa <Principe.Vanessa@epa.gov>; Wilson, Gregory <Wilson.Gregory@epa.gov>; michael.j.green-1@nasa.gov; wayne.yoder@dhs.gov; jfarrell@arctic.gov
Subject: ICCOPR Presentations (Reduced Size PDF)

Good morning ICCOPR Members,

As discussed, attached is a PDF with all of the presentations and agency updates slides. I had to reduce the size of the file to send it so please let me know if you want to see an original of one particular presentation.

Additionally, the draft minutes will go out for your review next week. Thank you!

Very respectfully,

LT Becca Brooks
U.S. Coast Guard Headquarters STOP 7516
Office of Marine Environmental Response Policy (CG-MER-3)
2703 Martin Luther King Jr. Ave SE
Washington, DC 20593-7516
Phone: 202-372-2259

To: Mike Fulton - NOAA Federal[mike.fulton@noaa.gov]
From: Conmy, Robyn
Sent: Fri 7/10/2015 1:00:50 PM
Subject: dispersant

Hi Mike,

I couldn't recall if you said your lab has finasol and corexit in stock for testing? If so, would you have any to share with us? We are running low and trying secure a liter or 2 of each.

Thanks,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

To: Clark, Patrick[Clark.Patrick@epa.gov]
From: Conmy, Robyn
Sent: Thur 5/12/2016 11:04:08 AM
Subject: RE: Availability of COREXIT Products for Testing
US EPA - 2016-E10-01.pdf

This is what they sent. No CAS number, but only the name of the product since they use a numbering system for each product (e.g. Corexit 9500A). Hope that is sufficient.

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Clark, Patrick
Sent: Wednesday, May 11, 2016 1:10 PM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Hey Robyn, I need a quote or something from Nalco with the product , amount, CAS #'s if applicable, phone # , etc so I can put a PR in for it. Once it is signed off on by 6 people andsent back to me I can call up Nalco and order it on our card. I have to tell them the card # and not send it by email. Once you get the info to me I can order it. thanks,Pat

From: Conmy, Robyn

Sent: Wednesday, May 11, 2016 11:14 AM
To: Clark, Patrick <Clark.Patrick@epa.gov>
Subject: FW: Availability of COREXIT Products for Testing

Hi Pat,

Below is the information for us to order a shipment of dispersants from Nalco. I've already spoken to Debby at Nalco about what is needed. She says that government purchase cards are fine and there is no tax listed on the quote. Can you send to her the relevant information so the dispersant can be shiiped?

Thanks,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Theriot, Debby [mailto:Debby.Theriot@nalco.com]
Sent: Tuesday, May 10, 2016 12:30 PM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>

Subject: RE: Availability of COREXIT Products for Testing

Hello Robyn,

Will you make payment based on receipt of the quotation or issue a PO for invoicing?

Accounting has provided the details below for taking credit card payment. Can you indicate the information and send back to me. No need to keep the underlines, I know they become a nuisance.

Please get the following information and send it to me. Once the PO is invoiced, I will pay it with the credit card.

CREDIT CARD INFORMATION:

- Credit card # ____

- Expiration Date: ____

- Choose one (mark with an X): __Visa __Mastercard __Amex

CARDHOLDER INFORMATION:

- Cardholder's Name: ______________________________________

- Cardholder's Phone#: ____________________________________

CALLER INFORMATION:

- Caller's Name: ____

- Caller's Phone#: ____

From: Conmy, Robyn [mailto:Conmy.Robyn@epa.gov]
Sent: Tuesday, May 10, 2016 11:14 AM
To: Theriot, Debby
Subject: RE: Availability of COREXIT Products for Testing

Thank you Debby. And does Nalco accept government credit cards?

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Theriot, Debby [mailto:Debby.Theriot@nalco.com]
Sent: Tuesday, May 10, 2016 12:12 PM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Robyn,

Thank you for the reminder.

Please see the attached quotation listing the product request. Pricing is the same for these products on a global basis.

Debby Theriot

Nalco Environmental Solutions LLC

7705 Highway 90-A

Sugar Land, TX 77478

debby.theriot@nalco.com

www.nalcoesllc.com

NALCO
Environmental
Solutions LLC

From: Conmy, Robyn [mailto:Conmy.Robyn@epa.gov]
Sent: Tuesday, May 10, 2016 6:29 AM
To: Theriot, Debby
Subject: RE: Availability of COREXIT Products for Testing

Hello Debby,

Keep in mind that we will need to pay for the product prior to Nalco shipping it to us. When you have the invoice, please send it our way for payment.

Thank you,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Theriot, Debby [mailto:Debby.Theriot@nalco.com]
Sent: Thursday, April 28, 2016 11:19 AM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>; Principe, Vanessa <Principe.Vanessa@epa.gov>
Cc: Matthiessen, Craig <Matthiessen.Craig@epa.gov>; Wilson, Gregory <Wilson.Gregory@epa.gov>; DeHaven, Leigh <DeHaven.Leigh@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Thank you Robyn,

I've added your request to the queue and will follow up for status.

debby

From: Conmy, Robyn [mailto:Conmy.Robyn@epa.gov]
Sent: Thursday, April 28, 2016 6:22 AM
To: Principe, Vanessa; Theriot, Debby
Cc: Matthiessen, Craig; Wilson, Gregory; DeHaven, Leigh
Subject: RE: Availability of COREXIT Products for Testing

Hello Debby,

As Vanessa stated in her email, EPA safeguards CBI, which extends to your products. As for the shipping information, please use my contact information below and add 'mail stop 173' to the street address. Yes, we will need an invoice for the products, which can be paid to you via credit card. Thank you for making arrangements for us to purchase the samples.

Cheers,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Principe, Vanessa
Sent: Wednesday, April 27, 2016 3:59 PM
To: Theriot, Debby <Debby.Theriot@nalco.com>
Cc: Matthiessen, Craig <Matthiessen.Craig@epa.gov>; Wilson, Gregory <Wilson.Gregory@epa.gov>; DeHaven, Leigh <DeHaven.Leigh@epa.gov>; Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Debby:

As mentioned in my prior email, EPA safeguards CBI information under the requirements in 40 CFR Part 2, Subpart B. Specifically, given your products are already listed in the Product Schedule, the current regulatory requirements apply, and the CBI safeguards are established under 40 CFR Part 300, Subpart J. We will continue to treat all materials claimed as CBI in accordance with our CBI regulations. Please be sure to claim CBI for the products when you send them to EPA to ensure that they will be treated as per above. Please note: we will be testing the products for toxicity and efficacy, and any EPA-generated results from those tests will not be considered CBI.

Thanks again for all your help, Vanessa

From: Theriot, Debby [mailto:Debby.Theriot@nalco.com]
Sent: Wednesday, April 27, 2016 10:42 AM
To: Principe, Vanessa <Principe.Vanessa@epa.gov>
Cc: Matthiessen, Craig <Matthiessen.Craig@epa.gov>; Wilson, Gregory <Wilson.Gregory@epa.gov>; DeHaven, Leigh <DeHaven.Leigh@epa.gov>; Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Thanks for the details Vanessa. We have never charged for samples, so I'll have to work on this arrangement. We will probably need to generate a manual invoice, called a "debit memo".

Market price per gallon for each product is below:

EC9500A $45

EC9500B $45

EC9527A $47

Robyn, please send the shipping details and let me know if you need to provide a PO so I can write up a quotation. Also, are you able to confirm the confidentiality with respect to non-analysis and disclosure of the formula, as requested by our legal team?

Thanks,

debby

From: Principe, Vanessa [mailto:Principe.Vanessa@epa.gov]
Sent: Wednesday, April 27, 2016 8:48 AM
To: Theriot, Debby
Cc: Matthiessen, Craig; Wilson, Gregory; DeHaven, Leigh; Conmy, Robyn
Subject: RE: Availability of COREXIT Products for Testing

Debby:

Thank you for following up on this request.

EPA's Office of Research and Development (ORD) will be conducting the dispersant studies. The contact person for details of the purchase is Dr. Robyn Conmy of ORD. She can be reached at (513) 569-7090 and can get you the shipping details.

We appreciate the offer to provide the samples at no cost. However, to avoid the perception of conflicts of interest we make it a practice to purchase these products, even if it is for a nominal fee. At this time we are seeking 2 U.S. gallons of each of COREXIT EC9527A, EC9500A and EC9500B.

Again, we appreciate your time and attention to this request. Please feel free to contact me as well if you have any questions/concerns.

Thank you, Vanessa

From: Theriot, Debby [mailto:Debby.Theriot@nalco.com]
Sent: Wednesday, April 27, 2016 7:28 AM
To: Principe, Vanessa <Principe.Vanessa@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Hi Vanessa,

If you can provide shipping details I can have the order placed in the queue.

Thanks,

debby

From: Theriot, Debby
Sent: Friday, April 22, 2016 3:02 PM
To: 'Principe, Vanessa'
Cc: Wilson, Gregory; Conmy, Robyn; Matthiessen, Craig; DeHaven, Leigh
Subject: RE: Availability of COREXIT Products for Testing

Hi Vanessa,

I have approval from legal to proceed without the need for NDA. They just ask that we "confirm that the formulation will not be disclosed". I will have the sample team pull these for you and prepare for shipment. Please advise the shipping address.

Samples of products are provide at no cost.

Thanks,

Debby Theriot

Nalco Environmental Solutions LLC

7705 Highway 90-A

Sugar Land, TX 77478

832.851.5164 cell

debby.theriot@nalco.com

www.nalcoesllc.com

From: Principe, Vanessa [mailto:Principe.Vanessa@epa.gov]
Sent: Thursday, April 21, 2016 3:50 PM
To: Theriot, Debby
Cc: Wilson, Gregory; Conmy, Robyn; Matthiessen, Craig; DeHaven, Leigh
Subject: RE: Availability of COREXIT Products for Testing

Debby:

Thank you for providing us with the NDA form.

It appears that your concern is for the protection of Confidential Business Information (CBI) specific to the formulation of your products. EPA safeguards CBI information under the requirements in 40 CFR Part 2, Subpart B. Specifically, for the products we are seeking, and which are already listed in the Product Schedule, current regulatory requirements address CBI under 40 CFR Part 300, Subpart J. These provisions should address your CBI concerns. EPA cannot enter into an NDA addressing CBI as it is bound by its regulations on such matters.

We are still interested in purchasing samples of these products for the purposes of both toxicity and efficacy testing. Given that the product testing is intended to support both regulatory actions under Subpart J and our general research in the area of oil spill response, any toxicity and efficacy testing results would not be considered CBI.

Please advise on how to proceed with this purchase.

Again, thank you for your attention to this matter,

Vanessa

From: Theriot, Debby [mailto:Debby.Theriot@nalco.com]
Sent: Wednesday, April 20, 2016 1:09 PM
To: Principe, Vanessa <Principe.Vanessa@epa.gov>
Cc: Wilson, Gregory <Wilson.Gregory@epa.gov>; Conmy, Robyn <Conmy.Robyn@epa.gov>; Matthiessen, Craig <Matthiessen.Craig@epa.gov>; DeHaven, Leigh <DeHaven.Leigh@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Hi Vanessa,

The standard format is attached. Details and scope are filled in by our paralegal once we receive from the requesting party.

debby

From: Principe, Vanessa [mailto:Principe.Vanessa@epa.gov]
Sent: Tuesday, April 19, 2016 1:33 PM
To: Theriot, Debby
Cc: Wilson, Gregory; Conmy, Robyn; Matthiessen, Craig; DeHaven, Leigh
Subject: RE: Availability of COREXIT Products for Testing

Ms. Theriot:

Thank you for getting back to me. My apologies, but my voice mail did not have any recorded messages from you.

Could you please send us a copy of your NDA for our Office of General Counsel to review?

Thank you for your attention to this matter,

Vanessa

From: Theriot, Debby [mailto:Debby.Theriot@nalco.com]
Sent: Tuesday, April 19, 2016 1:59 PM
To: Principe, Vanessa <Principe.Vanessa@epa.gov>
Cc: Wilson, Gregory <Wilson.Gregory@epa.gov>; Conmy, Robyn <Conmy.Robyn@epa.gov>; Matthiessen, Craig <Matthiessen.Craig@epa.gov>; DeHaven, Leigh

<DeHaven.Leigh@epa.gov>
Subject: RE: Availability of COREXIT Products for Testing

Hi Vanessa,

I believe I left a voicemail in return last week. For the release of products for testing, we require testing details for each product to be disclosed and NDA to be executed. Are you able to assist in the process?

I will be able to release samples free of any cost to you once the NDA's are fully executed.

Debby Theriot

Nalco Environmental Solutions LLC

7705 Highway 90-A

Sugar Land, TX 77478

832.851.5164 cell

debby.theriot@nalco.com

www.nalcoesllc.com

NALCO
Environmental
Solutions LLC

From: Principe, Vanessa [mailto:Principe.Vanessa@epa.gov]
Sent: Monday, April 18, 2016 11:10 AM
To: Theriot, Debby
Cc: Wilson, Gregory; Conmy, Robyn; Matthiessen, Craig; DeHaven, Leigh
Subject: Availability of COREXIT Products for Testing

Ms. Theriot,

This follows up my voice mails of last week and today.

Per my message, EPA is seeking to acquire a number of dispersant products listed on the NCP Subpart J Product Schedule for the purposes of both toxicity and efficacy testing. The product testing is intended to further inform currently proposed regulatory actions under Subpart J of the National Contingency Plan. The products will in addition be used to support our general research in the area of oil spill response.

Three of your products [COREXIT EC9527A, EC9500A and EC9500B] have been identified as of interest, as they are commonly stockpiled in the U.S. Not only could these products be encountered when presented with a response situation, but including these dispersant products in toxicity and efficacy testing studies will also allow for comparison and consistency with other existing and ongoing studies by EPA and other federal agencies. EPA's Office of Research and Development (ORD) will be conducting the dispersant studies.

At this time we are seeking 2 U.S. gallons of each of the products.

You can contact either me or Greg Wilson at 202-564-7989. We appreciate your time and attention to this request and look forward to talking to you.

Respectfully,

Vanessa Principe

Vanessa Principe

202-564-7913

Chemical Engineer

Office Of Emergency Management

Office of Land and Emergency Management

U.S. EPA

CONFIDENTIALITY NOTICE: This e-mail communication and any attachments may contain proprietary and privileged information for the use of the designated recipients named above. Any unauthorized review, use, disclosure or distribution is prohibited. If you are not the intended recipient, please contact the sender by reply e-mail and destroy all copies of the original message.

CONFIDENTIALITY NOTICE: This e-mail communication and any attachments may contain proprietary and privileged information for the use of the designated recipients named above. Any unauthorized review, use, disclosure or distribution is prohibited. If you are not the intended recipient, please contact the sender by reply e-mail and destroy all copies of the original message.

CONFIDENTIALITY NOTICE: This e-mail communication and any attachments may contain proprietary and privileged information for the use of the designated recipients named above. Any unauthorized review, use, disclosure or distribution is prohibited. If you are not the intended recipient, please contact the sender by reply e-mail and destroy all copies of the original message.

CONFIDENTIALITY NOTICE: This e-mail communication and any attachments may contain

contain proprietary and privileged information for the use of the designated recipients named above. Any unauthorized review, use, disclosure or distribution is prohibited. If you are not the intended recipient, please contact the sender by reply e-mail and destroy all copies of the original message.

CONFIDENTIALITY NOTICE: This e-mail communication and any attachments may contain proprietary and privileged information for the use of the designated recipients named above. Any unauthorized review, use, disclosure or distribution is prohibited. If you are not the intended recipient, please contact the sender by reply e-mail and destroy all copies of the original message.

NALCO Environmental Solutions LLC

QUOTATION

No. **2016-E10-01**
Valid: **30 Days**

Seller (Name and Address)	Quotation Date:
Nalco Environmental Solutions LLC 7705 Highway 90-A Sugar Land TX 77478 Attn: Debby Theriot	May 10, 2016 Other references (Include Purchasers Order Number)
Consignee (Name and Address)	Purchasers Name and Address (If other than Consignee) Robyn N. Conmy, PhD USEPA/ NRMRL / LRPCD Mail Stop 73 25 West MLK Drive Cincinnati, OH 45268 (513) 569-7090
Remit to: Company Code: 1080 Account Name: Nalco Environmental Solutions LLC Bank Name: Bank of America ABA: 026009593 SWIFT: BOFAUS3N Account Number: 4427147746 IBAN number: N/A Currency: USD	Country Of Origin of Goods USA
8. Transportation: Give Mode and Place of Direct Shipment	9. Conditions of Sale and Terms of Payment (i.e. Sale, Consignment, Leased Goods, etc.) EXW - SUGAR LAND, TX USA Terms of Payment / Currency of Settlement 30 days from delivery

Quantity	Description	13. Quantity (State Unit)		14. Unit Price	15. Total
2	COREXIT® EC9500A	1	gals	$45.00	$90.00
2	COREXIT® EC9500B	1	gals	$45.00	$90.00
2	COREXIT® EC9527A	1	gals	$47.00	$94.00
	estimated costs			**Total Value**	**$274.00** USD

EXW - SUGAR LAND, TX, USA
Nalco Terms and Conditions apply to this Quotation
Indemnity Agreement necessary for order processing
Please submit Tax Exemption Certificate (if necessary)
Orders contingent on legal and credit review
Order contingent on regulatory approval

I hereby certify that the above bill is correct and just; and that the said goods are the product of the soil or industry of the United States of America. These commodities, technology, or software were exported from the United States in accordance with the export administration regulations for the ultimate destination - Argentina Diversion contrary to U.S. law is prohibited.

We Certify this invoice is true and correct:
Nalco Environmental Solutions LLC

Subsea oil plume simulations: Tracking oil droplet size distribution and fluorescence within high release jets

R.N. Conmy[1], B. Robinson[2], T. King[2], M. I. Abercrombie[3], S. Ryan[2], C. McIntyre[2], M. Boufadel[4] K. Lee[2,5]

[1]U.S. Environmental Protection Agency, Office of Research and Development, NRMRL

[2] Bedford Institute of Oceanography, Dept. Fisheries and Oceans Canada

[3]University of South Florida, College of Marine Science

[4] New Jersey Institute of Technology

[5] CSIRO Australia

Ocean Optics
Oct 23-28, 2016 Victoria BC
Environmental Management Session

Optical measurements have been used during oil spill response for more than three decades to determine oil presence in slicks and plumes. Oil surveillance ranges from simple (human eyeball) to the sophisticated (sensors on AUVs, aircraft, satellites). In situ fluorometers and particle size analyzers were deployed during the Deepwater Horizon (DWH) Gulf of Mexico oil spill to track shallow and deep subsea plumes. Uncertainties regarding instrument specifications and capabilities necessitated performance testing of sensors exposed to simulated, dispersed oil plumes. Presented here are results of 72 wave tank experiments conducted at the Bedford Institute of Oceanography. Examined were simulations of subsea releases with varying parameters such as oil release rate, oil temperature (reservoir temp ~ 80 °C), water temperature (<8 °C and >15 °C), oil type, dispersant type (Corexit 9500 and Finasol OSR52) and dispersant to oil ratio (DOR). Plumes of Alaskan North Slope Crude, South Louisiana Crude and IFO-120 were tracked using in situ fluorescence, droplet size distribution (DSD; LISST 100X), total petroleum hydrocarbons (TPH), benzene-toluene-ethylbenzene-xylene (BTEX) and excitation-emission matrix spectroscopy. Results offer valuable information on the behavior and dispersibility of oils over a range of viscosity and composition. Findings have implications for fate & transport models, where DSD, chemistry and fluorescence are all impacted by release variables. Research supported by the Bureau of Safety and Environmental Enforcement.

To: McClellan, Kim[Mcclellan.Kim@epa.gov]
From: Conmy, Robyn
Sent: Tue 1/19/2016 7:35:35 PM
Subject: posters to be added to existing STICS entries
3.Dilbit-Ruta_ORD 013912.pptx
4.Solidifier-Devi_ORD 013921.pptx
1.Finasol-YuZhang_ORD 013915.pptx
2.Heavy Fuel Oil_MobingZhuang_ORD 013917.pptx

Hi Kim,

Attached are 4 posters that need to be added to existing STICS entries below. Powerpoint file names have the first author names and the STICS numbers in.

ORD-013915

Biodegradation of Finasol OSR 52 and Dispersed Alaska North Slope (ANS) Crude Oil at 5 °C and 25 °C

Yu Zhang, Pablo Campo, Ruta Suresh Deshpande, Mobing Zhuang, and Robyn N. Conmy

ORD-013917

Biodegradability of Dispersed Heavy Fuel Oil at 5 and 25 °C

Mobing Zhuang, Gulizhaer Abulikemu, Pablo Campo-Moreno, Makram Suidan, Albert D. Venosa (retired), and Robyn N. Conmy

ORD-013912

Biodegradability Of Diluted Bitumen Oil By Kalamazoo River Cultures In Freshwater

Ruta Suresh Deshpande, Pablo Campo-Moreno, Robyn N. Conmy

ORD-013921

Evaluation of Sorbent and Solidifier Properties and their Impact on Oil Removal Efficiency

Devi Sundaravadivelu, M. T. Suidan, A. D. Venosa (retired), P. Campo, R. N. Conmy

Thanks for your help! There will be 2 more tomorrow that are the oral presentation slides.

Cheers,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

United States Environmental Protection Agency

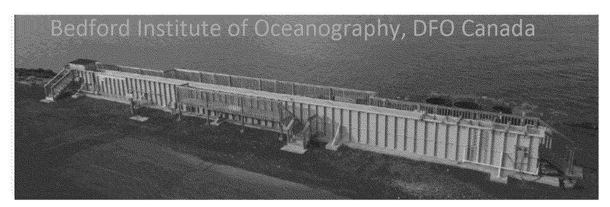
Actionable Science for Communities

SHC 3.62.1 Wave Tank Oil Plume Simulations

Robyn Conmy, NRMRL

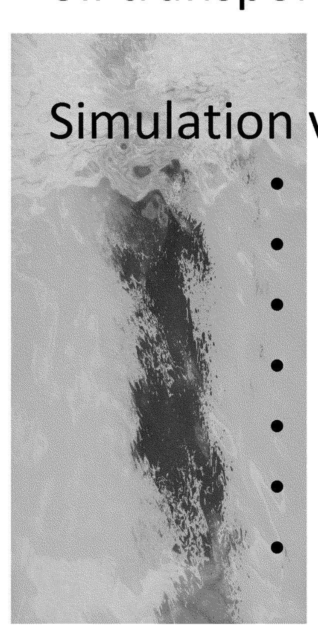
Purpose/Utility of Research

Oil plume dispersion simulation experiments have been conducted over the past 5 years in collaboration with the Canadian Government within the large-scale wave tank at the Bedford Institute of Oceanography.



This research is critical for advancing science with respect to aspects of spill preparedness, response, and remediation; particularly during Spills of National Significance.

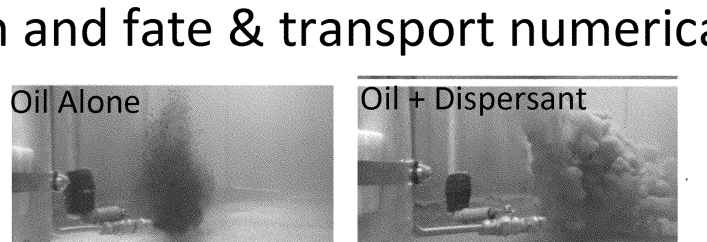
Optical sensors are used during oil spill response to determine oil presence in slicks and plumes. *In situ* sensors were deployed during the Deepwater Horizon (DWH) oil spill to track shallow and deep subsea plumes. Tank simulations address knowledge gaps in uncertainties regarding sensor capabilities, plume formation, droplet size distribution (DSD), dispersion effectiveness, and oil transport.



Simulation variables include:

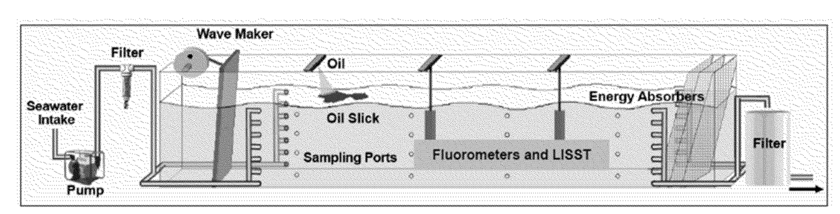
- Oil release type
- Oil temperature (reservoir temp ~ 80 °C)
- Water temperature (5 °C - 22 °C)
- Oil type (ANS, SLC, IFO-120)
- Dispersant (Corexit 9500; Finasol OSR52)
- Dispersant to oil ratio (DOR)
- Salinity (20-100 ppt)

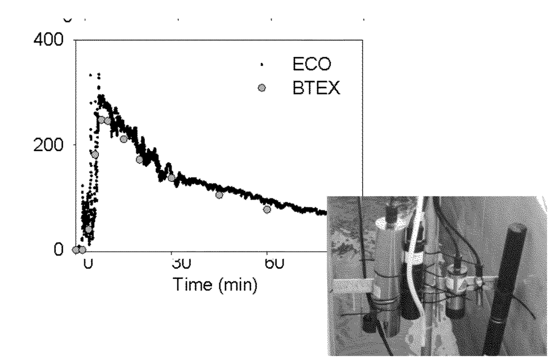
Results offer information on the behavior and dispersibility of oils, with implications for droplet formation and fate & transport numerical models.

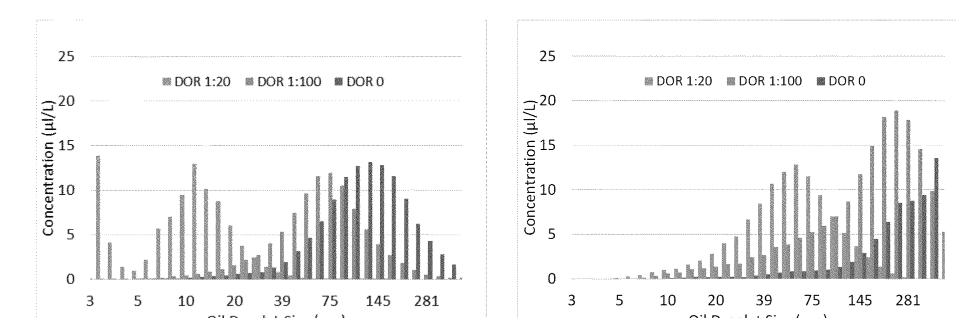


Highlights

- Simulation experiments provide for evaluating factors that influence oil dispersion and how forensic field sensors detect dispersed oils.
- Evaluation of *in situ* fluorometers used during the *Deepwater Horizon* oil spill demonstrated a detection of 300 ppb oil, refuting previous misconceptions of 1 ppm oil detection limit.
- Simulation research is critical for the Agency's spill preparedness and response efforts.
- Jet simulations inform SSDU (Sub-Surface Dispersant Use) planning by EPA OLEM, which coincides with the API (American Petroleum Institute) efforts.
- On-going simulations include dispersion under hypersaline water conditions for Arctic and deep spill preparedness.







Application & Translation

40 CFR Decision-rule Amendments

Performance evaluation of sensors via a novel approach for sensor assessment, calibration, and appropriateness was published in Conmy *et al.,* 2014 (ES&T). This manuscript serves as a citation within the Federal Register proposed decision-rule amendments to the 40 CFR § 300.900-920 subpart J for spill monitoring requirements.

Expert Witness Deposition

Conmy *et al.,* 2014 was also used by the Department of Justice as material during depositions for the DWH Clean Water Act Penalties trial.

EPA 600/R-16/152 Federal Report

A recent report summarized the high-pressure jet oil releases simulations for evaluating droplet fractionation and tuning the oil droplet formation numerical model, JETLAG used during DWH.

Scaling Up

BIO wave tank simulations have now translated to work at the larger OHMSETT facility.

Intended End users

- EPA Office of Land and Emergency Management
- National and Regional Response Teams
- Federal On-Scene Coordinators
- Oil spill emergency responders

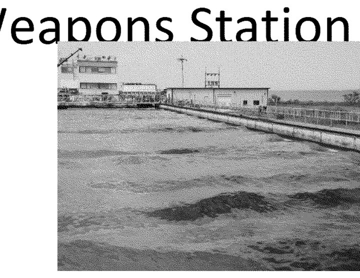
Research products are used to:

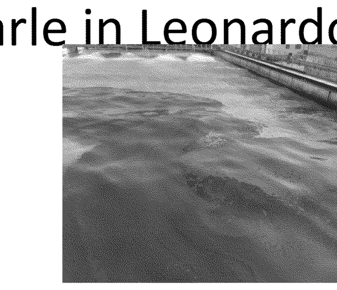
1) Improve response monitoring guidance
2) Assist with Area Contingency Plans
3) Enhance spill preparedness
4) Serve as citations in 40 CFR decision rules

Lessons Learned

In US waters, intentional releases of oil are not permissible. For research purposes, permits are difficult to obtain and time-prohibited. Thus, oil dispersion simulation large-scale wave tanks are vital to advancing the science forward. This type of research has a large return on investment for the EPA and the oil spill community.

Research findings have translated to larger scale experiments at the US operated OHMSETT facility at Weapons Station Earle in Leonardo, NJ.





EPA initiated and executed Interagency Agreements (funds in to EPA) with Department of Interior's Bureau of Safety and Environmental Enforcement and the Department of Fisheries and Oceans Canada to conduct jet release research. Sensor calibration research was funded through NOAA.

Biodegradability of Different Initial Concentrations of Alaska North Slope Crude Oil Dispersed with Corexit C9500

Mobing Zhuang[1], Gulizhaer Abulikemu[2], Pablo Campo[3*], William Platten III[4], Makram T. Suidan[5], Albert D. Venosa (retired)[4]and Robyn N. Conmy[4]

1 Department of Biomedical, Chemical and Environmental Engineering, University of Cincinnati, 2901 Woodside Drive, Cincinnati, OH 45221, USA

2 Pegasus Technical Services Inc., 46 E Hollister St, Cincinnati, OH 45219 USA

3 Cranfield Water Science Institute, Cranfield University, Cranfield, Beds, MK43 0AL, UK

4 U.S. Environmental Protection Agency, NRMRL, 26 W. MLK Drive Cincinnati, OH, 45268, USA

5 Faculty of Engineering and Architecture, American University of Beirut, Bechtel Engineering Bldg. - 3rd flr. - Room 308 P.O. Box: 11-0236 Riad El Solh 1107 2020, Beirut, Lebanon

*Corresponding author: Pablo Campo
Tel: +44 (0)1234 754332
E-mail address: p.campo-moreno@cranfield.ac.uk

ABSTRACT

Laboratory experiments were conducted using Alaska North Slope crude oil (ANS) and the dispersant Corexit 9500 (C9500) to study the biodegradability of ANS alone, ANS dispersed with C9500 at a dispersant-to-oil ratio of 1:25. To determine the role that substrate concentration plays in biodegradation kinetics, oil loads of 1,000 and 40 ppm (v:v) were compared at 25 and 5 °C. The biodegradation rate of dioctyl sodium sulfosuccinate (DOSS), which is an anionic surfactant in C9500, by the meso culture (25 °C) was approximately an order of magnitude faster in the high concentration experiment than in the low concentration experiment. At the lower temperature, the deep-water culture cryo (5 °C) had limited ability to metabolize DOSS regardless of the initial concentrations. Uptake of oil components was favored by the presence of dispersant as C9500 shortened lag phases and enhanced biodegradation rates. Alkanes and PAHs were degraded more rapidly in the high concentration samples. In the low concentration experiment, the percentage of alkanes persisting was higher than in the high concentration experiment (8-18% vs. below 1%). No significant lag period in PAH biodegradation was observed in the high oil concentration experiment compared to the low oil concentration experiment where a lag period of 12 to 16 d was observed. The extent of biodegradation of some of the less soluble aromatics increased by 4-86% under low oil concentration conditions.

KEYWORDS

Corexit 9500, biodegradation, initial oil concentration

INTRODUCTION

To minimize the impact of oil spills, responders adopt the Net Environmental Benefit Analysis, this is, any response technique should decrease the environmental costs rather than increase them (API, 2013). When mechanical recovery or in situ burning cannot achieve the goal of protecting shorelines from oil, the impact of using dispersants is likely outweighed by the benefits, which include keeping oil from sensitive areas and speeding up biodegradation by breaking an oil slick into small droplets (Prince, 2015). Thus, it is important to study the biodegradability of dispersants and dispersed oil under various conditions for better informed use in future applications.

In the aftermath of the Deepwater Horizon blowout in the Gulf of Mexico (GOM), comprehensive monitoring of dispersant Corexit 9500 (C9500) and hydrocarbons in both surface and subsurface environments took place. In samples collected near the Macondo well, concentrations of dioctyl sodium sulfosuccinate (DOSS), an anionic surfactant present in C9500, ranged from 0.4 to 12 μg/L (Kujawinski et al., 2011). After the spill, Gray et al. (2014) sampled at GOM different locations and detected DOSS in subsurface waters at concentrations below 40 μg/L, while in one surface water sample close to the wellhead the value exceeded 200 μg/L. In terms of oil concentration, Lee et al. (2013) pointed out that the combination of turbulence on the GOM surface and the dispersant application could rapidly decrease oil concentrations to below 100 mg/L, dropping even further over time. Hence, these researchers recommended that biodegradation tests of dispersed oil should be conducted under more dilute concentrations to mimic real conditions.

Most studies published on biodegradation of oil and dispersants prior to the Deepwater incident had been conducted at concentrations well-above the reported in situ levels (Operational Science Advisory Team, 2010; Prince, 2015). Several studies assessing biodegradation of oil dispersed by C9500 used initial oil and dispersant concentrations from 100 to 4,500 mg/L, with a dispersant-to-oil ratios (DOR) of 1:10, 1:20, or 1:25 (Campo et al., 2013; Lindstrom and Braddock, 2002; Zahed et al., 2010). To our knowledge, few studies have been published on oil biodegradation with initial oil and dispersant concentrations below 100 ppm (Brakstad et al., 2015; Prince et al., 2013; Venosa and Holder, 2007). Thus our objective was to determine how the initial amounts of oil and dispersant affect their biodegradation. We conducted high and low oil concentration biodegradation experiments with Alaska North Slope crude oil (ANS) and C9500 at 5 and 25 °C. C9500 is a dispersant included in the National Contingency Plan Product Schedule and was applied to both the surface and submarine environment in the GOM (Operational Science Advisory Team, 2010). The biodegradation of DOSS, dispersed ANS, and ANS alone in high and low concentration experiments at 5 and 25 °C are reported in this paper.

MATERIALS AND METHODS

Chemicals and Reagents

The U.S. Environmental Protection Agency (EPA) provided the ANS and the dispersant C9500 (Nalco Naperville, IL) used in this study. Standards for DOSS and its deuterated surrogate (D_{17}-DOSS) were obtained from Aldrich (St. Louis, MO) and Isotec (Miamisburg, OH), respectively. Acetonitrile, deionized ultra-filtered water, and mineral salts were purchased from Fisher Scientific (Pittsburgh, PA). Dichloromethane (DCM) was obtained from Tedia (Fairfield, OH). Sylon CT (Sigma-Aldrich, St. Louis, MO) was used for the deactivation of the glassware to prevent adherence of oil and biomass to the sides of the flasks. The protease cocktail for inhibiting enzymatic activity was also acquired from Sigma-Aldrich (St. Louis, MO).

Protease Solution Preparation

Following the instruction provided with the protease cocktail, 5 mL dimethyl sulfoxide (DMSO) was added to 1,075 mg lyophilized powder, which was previously stored unopened at -20 °C. The solution was vortexed for ten minutes before the addition of 20 mL deionized water. The resulting solution was clear. The reconstituted protease solution contained the following inhibitors: 4-(2-aminoethyl) benzenesulfonyl fluoride hydrochloride (23 mM), ethylenediaminetetraacetic acid (100 mM), bestatin (2 mM), pepstatin A (0.3 mM), and E-64 (0.3 mM).

Artificial Seawater

GP2 medium was autoclaved at 121 °C for 30 min and then used as the sterile matrix in this study (Spotte et al., 1984). The salts in the GP2 medium, dissolved in DI water, were (expressed in g/L) NaCl (21.03), $MgCl_2 \cdot 6H_2O$ (9.5), Na_2SO_4 (3.52), $CaCl_2 \cdot 2H_2O$ (1.32), KCl (0.61), KBr (0.088), $NaB_4O_7 \cdot 10H_2O$ (0.034), $SrCl_2 \cdot 6H_2O$ (0.02), $NaHCO_3$ (0.17) $FeCl_3 \cdot 6H_2O$ (0.05), $Na_5P_3O_{10}$ (0.297) and KNO_3 (2.89). The GP2 pH was ≈ 7.5.

Microbial Cultures

The original cultures were isolated from the surface water of the GOM (meso) in the vicinity of the Macondo well and water close to the plume location at a depth of 1,240 m near the wellhead (cryo) by EPA's Gulf Breeze, FL research laboratory. Enriched inocula were procured as follows: in 2-L shake flasks, 2.5 mL SLC were added to 500 mL of the original unfiltered GOM seawater supplemented with 2.8 g/L KNO_3, 0.55 g/L NaP_3O_{10}. The flasks were rotated (400 rpm) at 5 °C (cryo culture) and 25 °C (meso culture). The adequate growth times were 7 d for the meso culture and 17 d for the cryo culture. After these periods, cells were harvested by centrifugation (6,000 × g for 30 min at 4 °C) and the pellets preserved in 10% glycerol at -70 °C. Before shipping to EPA-Cincinnati, 1 mL of each thawed culture were added to shake flasks containing 500 mL GP2 medium fortified with 2.5 mL of SLC. The meso culture was harvested after 6 days of growth and the cryo culture after 29 days. The cultures used in the experiments of this study were grown at EPA (Cincinnati, OH) by transferring the original cultures from EPA's Gulf Breeze to GP2 medium supplemented with South Louisiana crude oil (SLC). The meso culture was harvested after 3 weeks of growth and the cryo culture after 5 weeks. The harvested culture was processed in the same fashion as mentioned previously: centrifugation (6,000 × g for 30 min at 4 °C) and the pellets preserved in 10% glycerol at -70 °C. Upon use in experiments, the cultures were defrosted at room temperature, washed with 0.85% saline solution to remove glycerol, centrifuged, and brought back up to the frozen volume.

Experimental Setup and Sampling

A summary of the experimental setup is shown in Tables S1 and S2 for the high and low oil concentration experiments, respectively. For the high concentration experiments, 6 treatments were tested at 5 and 25 °C in triplicate: C9500 dispersant alone, ANS oil alone, ANS dispersed with C9500, and the corresponding killed controls (KCs). The 5 °C experiment required 11 sampling events in triplicate (0, 2, 4, 8, 12, 16, 24, 32, 40, 48 and 56 d), while 9 events were conducted at 25 °C (0, 2, 4, 8, 12, 16, 24, 32 and 40 d). At each sampling event, triplicate shake flasks of each treatment along with KCs were sacrificed, except for the ANS alone KCs which were analyzed at the beginning and end of the experiment.

The same treatments were included in the low concentration experiment, but both oil and dispersant concentrations were prepared at 4% of the initial loads used in the high concentration experiment. Additionally, a seventh treatment involved the use of triplicate KCs containing the enzyme protease (0.5 mL) to neutralize the enzymatic DOSS hydrolysis. This treatment was included only in the low concentration experiment. The sampling events were conducted similarly to the high concentration experiment with the exception of the protease treatment, which was sampled at 0, 12, 24, 35, 46 and 56 d and 0, 8, 18, 28, 38 and 48 d for the 5 and 25 °C experiments, respectively.

After all treatments were prepared, the appropriate cultures were spiked (0.5 mL) and the flasks were placed on orbital shakers. The shakers were operated at 200 rpm and kept in the appropriate constant temperature rooms until the expected sampling events. All KCs were sterilized by adding 1 mL sodium azide stock (50 g/L) into the 100 mL of GP2 medium.

High Concentration Treatments

To evaluate the biodegradation of dispersed oil, 2 L baffled beakers were used in which 40 μL of C9500 and 1,000 μL of ANS were added to 1,200 mL of GP2 to achieve a volumetric DOR ratio of 1:25. Subsequently, the beaker containing the mixture was shaken at 200 rpm for 10 minutes and then left stationary for an additional 10 min, then the dispersion was transferred to a 20-L continuously mixed carboy. The above procedure was repeated until the volume in the carboy reached 14 L. Subsequently, 100 mL aliquots of the mixtures were transferred to the shake flasks. The second treatment was for the evaluation of oil as the only substrate. ANS (100 μL) was added directly to shake flasks containing 100 mL sterile GP2 medium, which yielded an estimated oil concentration of 1,000 ppm by volume. The oil added to the ANS alone and dispersed ANS treatments aimed to result in the same oil concentration by volume. To evaluate the degradation of dispersant alone, 480 µL of C9500 was added to 14 L of sterile GP2 medium in a continuously mixed carboy; after 30 min, 100 mL aliquots of this mixture were dispensed into shake flasks for this treatment.

Low Concentration Treatments

To prepare the low concentration dispersed oil, a single batch of 1,200 mL GP2 was spiked with 200 µL ANS onto the water surface followed by addition of 8 µL C9500 onto the oil slick, which yielded a volumetric DOR of 1:25 in a 2 L baffled beaker. The shaker was started at a very slow speed and was ramped up to 200 rpm gradually. The beaker was placed on a shaker for 20 min and then remained stationary for 10 minutes. Subsequently, 3 L of the dispersion were poured into a 20 L carboy under continuous mixing and 12 L of sterile GP2 was added for dilution purposes. Overall, the oil and dispersant amounts in this treatment were approximately 4% of that in the high concentration experiment. Finally, shake flasks were filled with 100 mL aliquots of the diluted dispersed oil. Low concentration ANS alone was prepared by spiking approximately 4 µL of oil into shake flasks containing 100 mL sterile GP2, which yields an oil concentration of 40 ppm by volume (i.e., 4% of the high concentration oil alone experiment). The low concentration dispersant alone treatment was prepared in a single batch of sterile GP2 (14 L) spiked with approximately 20 µL of C9500. The batch was mixed for 30 minutes and, subsequently, 100 mL aliquots were transferred into the shake flasks.

Oil components and Dispersant Analysis

To monitor C9500 degradation, DOSS was measured by liquid chromatography tandem mass spectrometry (LC-MS/MS) following the Standard method ASTM D7730−11 (2011). The targeted oil components were pristane (PR), phytane (PH), normal paraffins (n-C_{10-35}) and 2-, 3- and 4-ring PAH compounds and their alkylated homologues (C_{0-4}-naphthalenes, C_{0-3}-fluorenes, C_{0-3}-dibenzothiophenes, C_{0-4}-phenanthrenes/anthracenes, C_{0-4}-napthbenzthiophenes, C_{0-2}-pyrenes, C_{0-4}-chrysenes). The concentrations of these analytes were normalized to hopane present in the oil (Prince et al., 1994). Details of oil extraction by DCM and sample preparation methods can be found elsewhere (Campo et al., 2013). For the high concentration experiment, oil analysis was conducted with a 6890 GC coupled with a 5973 mass spectrometry from Agilent (Palo Alto, CA). In the low concentration experiment, an Agilent (Palo Alto, CA) 7000 GC Triple Quad system was used. The quantification range for the single quad and triple quad mass spectrometry are 1-30 μg/L and 0.5-10 μg/L, respectively. In the case that the concentration of oil hydrocarbons is below the range, we used the quantification results as an estimation of the actual amount. The same column, a DB-5MS column (30m × 0.25mm, 0.25μm film thickness), was used to achieve chromatographic separation of analytes in both instruments. The method was a modification based on EPA Method 8270D (2007).

RESULTS AND DISCUSSION

Degradation of DOSS

High Concentration Experiment. Live samples revealed an extremely fast removal rate of DOSS at 25 °C (Fig. 1A-B, open symbols) with extents exceeding 95% after 2 d in dispersed oil (Fig. 1B) and 4 d in C9500 alone (Fig. 1A). The first order rate coefficients were -1.82 ± 0.25 d^{-1} (ANS+C9500) and -0.71 ± 0.024 d^{-1} (C9500 alone). The presence of oil enhanced DOSS biodegradation by a factor of approximately 2.6. Disappearance of DOSS was also observed in KCs at 25 °C, with zero order rates of -138 ± 7 and -221 ± 11 μg L^{-1} d^{-1} for C9500 alone (Fig.

1C) and dispersed oil (Fig. 1D), respectively. As monooctyl sulfosuccinate (MOSS) was found in KCs, Campo et al. (2013) explained this abiotic loss in terms of hydrolysis which was confirmed by (Batchu et al., 2014). The presence of oil significantly enhanced DOSS removal in KCs ($p < 0.0001$).

In contrast with the rapid removal of DOSS at 25 °C, the biotic and abiotic processes at 5 °C were much slower. DOSS persisted for 40 d before its concentration decreased in all treatments. The difference in DOSS concentration between live samples and parallel KCs in the dispersed oil treatment was statistically insignificant at days 48 ($p = 0.078$) and 56 ($p = 0.726$). In the C9500 alone treatment, DOSS was significantly lower in live samples than in KCs at days 48 ($p = 0.0015$) and day 56 ($p = 0.023$). These results point to biodegradation as the predominant DOSS removal mechanism as opposed to hydrolysis.

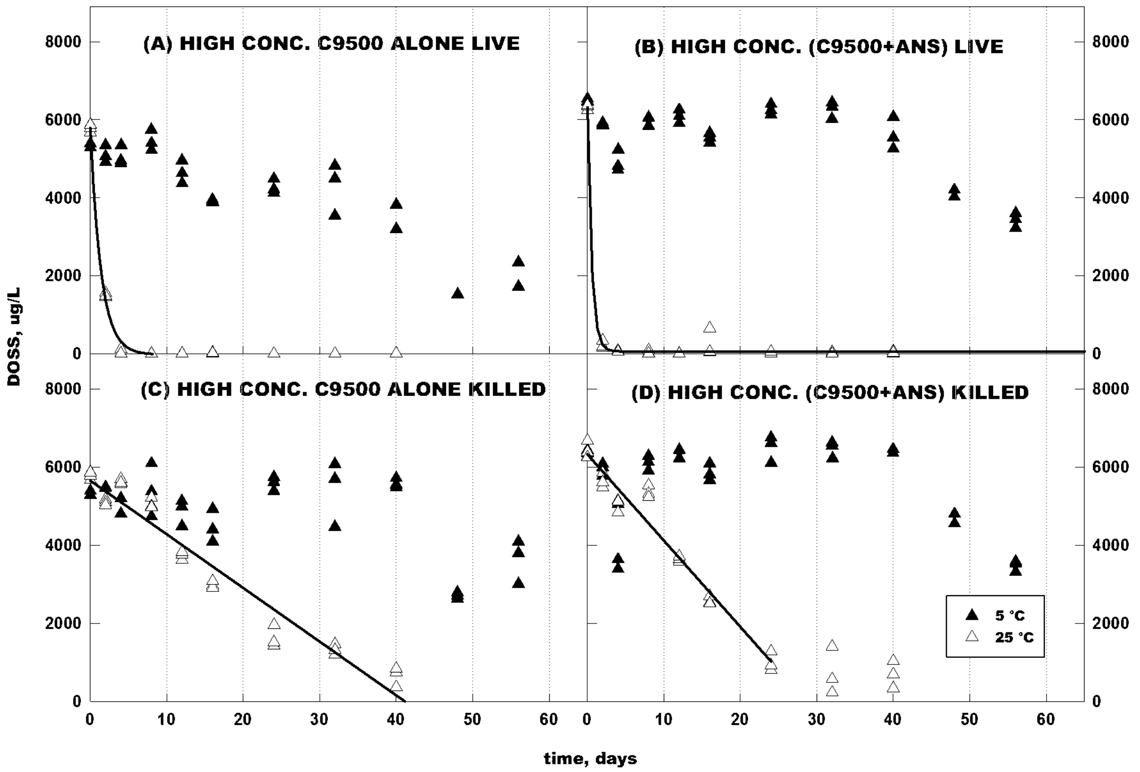


Figure 1. Disappearance of DOSS in high concentration experiment in the absence (A, C) and Presence (B, D) of ANS at 5 °C and 25 °C. Live samples are in panel A and B, whereas killed controls are in panels C and D.

Low Concentration Experiment. At 25 °C and for the dispersed oil treatment, no lag period was observed in DOSS uptake, which showed a first-order constant rate of -0.16 ± 0.015 d^{-1} (Fig. 2B). In the absence of oil (Fig. 2A), we observed an acclimation period of 2 d followed by DOSS biodegradation (-0.07 ± 0.009 d^{-1}). The presence of oil favored DOSS removal as was observed in the high concentration experiment . Removal extents over 95% for DOSS required 32 and 48 d in the presence and absence of oil, respectively. In the corresponding KCs, DOSS concentrations decreased following zero-order kinetics, with constant rates of -4.1 ± 0.3 µg L^{-1} d^{-1} (C9500 alone, Fig. 2C) and -5.1 ± 0.4 µg L^{-1} d^{-1} (C9500 and ANS, Fig. 2D).

For the high concentration experiment at 25 °C and regardless of the presence of oil, the time series concentration of DOSS in the live samples rapidly declined to zero and clearly separated from the values measured in the corresponding KCs. In the low concentration experiment, it appeared that DOSS disappearance with time in both treatments, C9500 alone and dispersed ANS, overlapped with the abiotic losses observed in the KCs (Fig. 2). To differentiate between microbial activity and hydrolysis, we compared by a *t*-test ($\alpha = 0.05$) the average DOSS concentrations measured in live samples with those values found in the parallel KCs. Live samples significantly departed from the controls after 4 d ($p = 0.0227$) and 16 d ($p = 0.0053$) in the presence and absence of ANS, respectively. At early stages in the experiment, we could not identify the predominant removal mechanism for DOSS but, eventually, microbial uptake prevailed as the main process in terms of rate and extent.

DOSS presented a faster microbial uptake at both the higher initial concentration and temperature. Nevertheless, based on our low concentration results, it is reasonable to infer that biodegradation of DOSS at the surface of GOM might not happen as rapidly since dilution and emulsification can attenuate the concentration of dispersant. In this fashion, DOSS was detected with a reporting limit of 0.25 μg L^{-1} and a highest concentration of 229 ±16 μg L^{-1} in surface water samples collected 1-2 months after the spill near the Macondo well (Gray et al., 2014).

DOSS concentration remained unchanged in live samples and KCs under 5 °C and low oiling conditions (Fig. 2, closed symbols). Such finding agreed with studies by Kujawinski et al. (2011) and Gray et al. (2014) who concluded that subsurface degradation of DOSS was minimal. Campo et al. (2013) observed no hydrolysis or biodegradation of DOSS in SLC at 5 °C within 42 d.

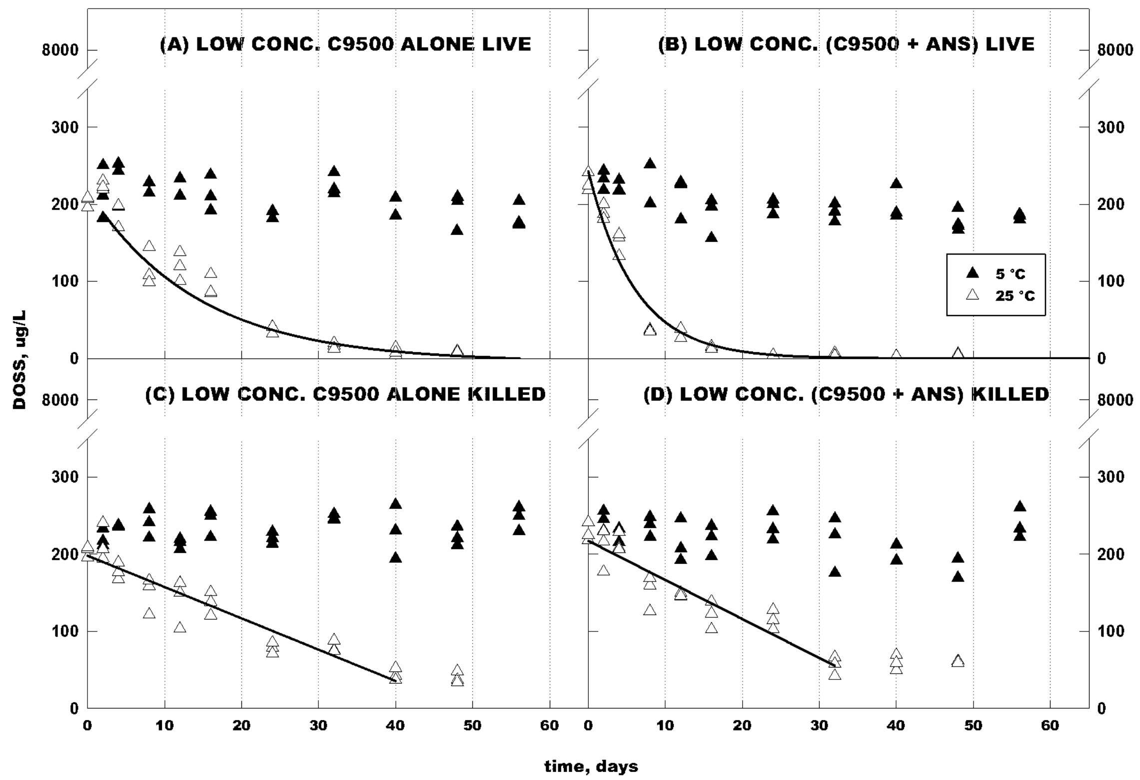


Figure 2. Disappearance of DOSS in low concentration experiment in the absence (A, C) and Presence (B, D) of ANS at 5 °C and 25 °C. Live samples are in panel A and B, whereas killed controls are in panels C and D.

We also included a series of dispersed oil KCs containing a protease cocktail (Fig. 3A), which inhibits enzymatic activity to clarify the abiotic DOSS disappearance. At 25 °C, the addition of inhibitor clearly slowed down the hydrolysis process as the zero-order rate constant in the protease KCs was -3.7 ± 0.4 μg L^{-1} d^{-1} (Fig. 3A) as opposed to -5.1 ± 0.4 μg L^{-1} d^{-1} (Fig. 3B) obtained for the regular KCs ($p = 0.021$). Such finding suggests the enzymatic nature of DOSS hydrolysis. Nevertheless, different enzymes may be involved in the process so that the protease cocktail could not block all of them. In the protease controls at 5 °C, DOSS persisted throughout the experiment as observed in the regular KCs for that temperature. This indicates that either the lower temperature attenuated DOSS breakdown,the cryo culture lacked the required enzymes, or a combination of both causes.

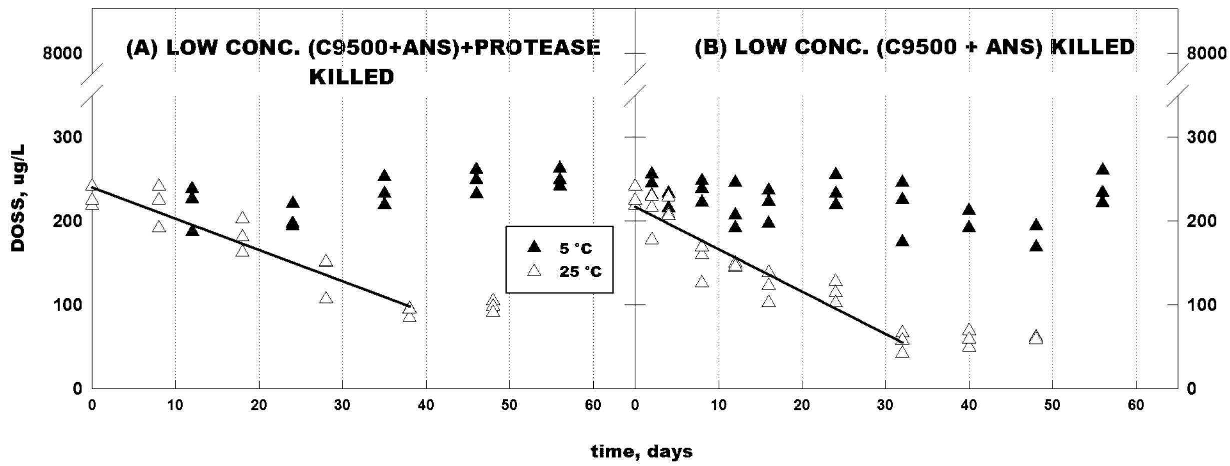


Figure 3. Disappearance of DOSS in low concentration dispersed oil killed controls in the presence (A) and absence (B) of protease at 5 and 25 °C.

Total Alkane Degradation

High Concentration Experiment. Total alkanes at both temperatures are presented in Fig. 4 A-B. At 25 °C, the meso culture metabolized the aliphatic fraction with a first-order rate constants of -0.91 ± 0.10 and -0.85 ± 0.04 d^{-1} in the absence and presence of C9500, respectively. For both treatments, the extent of removals reached 99% after 4 days. As expected, aliphatics degraded slower at 5 °C. In the dispersed oil treatment, this fraction followed first order kinetics (-0.24 ± 0.01 d^{-1}) while, for the oil alone samples, alkanes presented a linear decay during the first 8 d followed by first order kinetics of similar rate (-0.25 ± 0.03 d^{-1}). After days 16 (dispersed oil) and 24 (oil alone), the alkane extent of removal was 99% for the lower temperature.

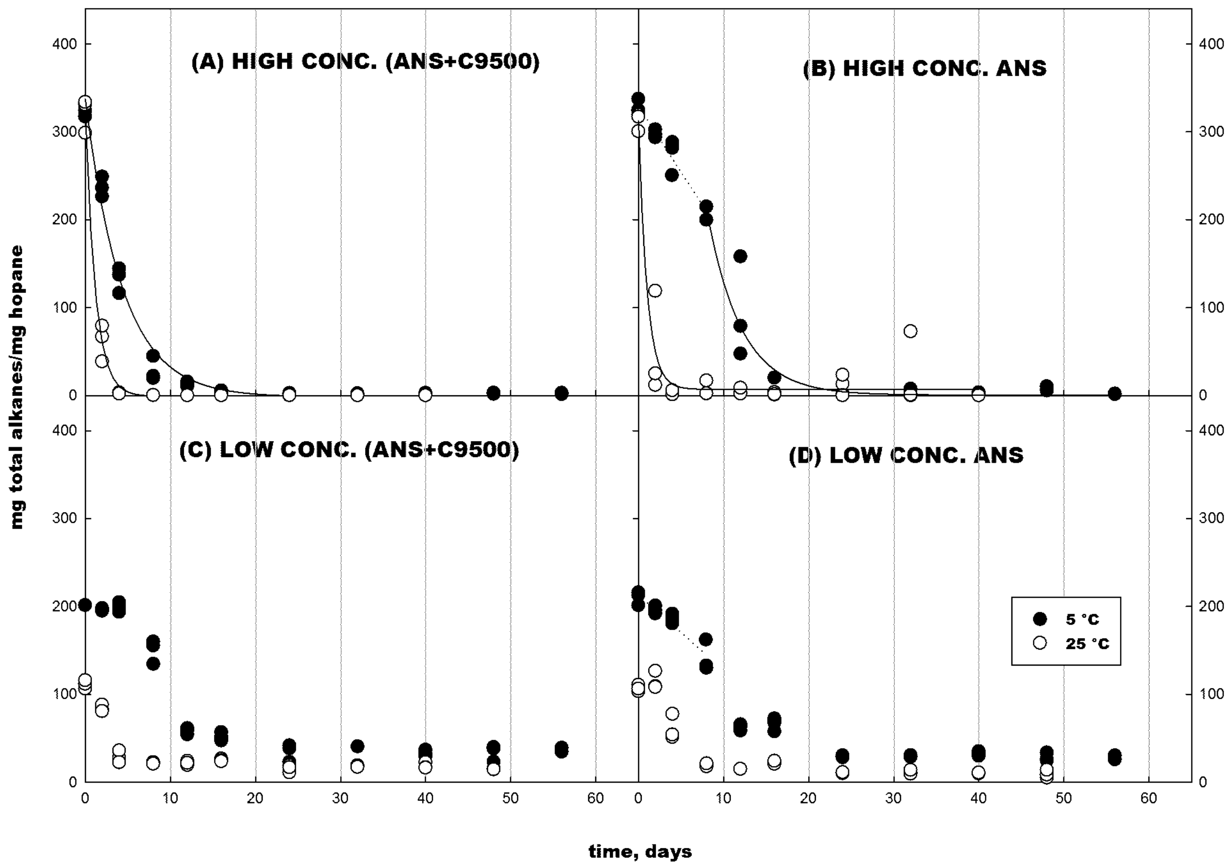


Figure 4. Biodegradation of hopane-normalized total alkanes at both temperatures in high concentration treatments (A, B) and low concentration treatments (C, D).

Low Concentration Experiment. In this experiment, the initial total alkane concentrations were considerably different at 5 and 25 °C (Fig. 4 C and D). In fact, the meso culture showed background concentrations of PAHs and hopane, the conservative biomarker to which all the target analytes concentrations are normalized. The hopane background levels were comparable to those measured in the initial oil added to the flasks. Hence, at time zero, the total alkane concentration normalized to hopane at 25 °C were almost half of the corresponding value at 5 °C.

At 25 °C, the alkane residual concentrations ranged from 8 to 18% of the initial values (Fig. 4 A and B). In the oil alone treatment, alkane biodegradation started after a lag phase of 2 d, while these organics were promptly metabolized in the dispersed oil treatment. At 5 °C, the cryo culture required 4 d for acclimation in the dispersed oil. In the absence of dispersant, after a slow and steady linear decay, fast disappearance of alkanes occurred between days 8 and 12. This suggests that C9500 reduced the length of the acclimation phase for alkane uptake.

Table 1 summarizes the actual concentrations of total alkanes (not normalized to hopane) for the first and last sampling event for both the high and low concentration experiments. It is noted that a higher alkane residual amount was observed in the low concentration experiment than the high concentration one. This was especially true considering the combination of high temperature and dispersant application, where the alkane concentrations were less than the detection limit and 142 ± 4 μg L^{-1} in the last sampling event of low concentration samples. One possible explanation is that carbon and energy sources were limited in the low concentration microcosms. Fewer microorganisms provided less microbial surface for hydrophobic compounds to interact with, which resulted in less complete degradation of alkanes.

Table 1. Average and standard deviations (sd) of total alkanes and PAHs concentration in the high and low concentration experiment at first and last sampling event.

			5 °C		25 °C		5 °C		25 °C	
Samples			ANS alone		ANS alone		ANS+C9500		ANS+C9500	
			average (μg/L)	sd	average (μg/L)	sd	average (μg/L)	sd	average (μg/L)	sd
High Conc.										
	Alkanes	**First**	47,400	604	43,300	9,390	24,600	973	27,200	126
		Last	201	26	36	42	186	52	0	0
	PAHs	**First**	14,500	110	13,700	3,090	7,310	323	8,790	94
		Last	3,040	281	2,470	300	1,300	74	1,270	158
Low Conc.										
	Alkanes	**First**	2,010	202	1,740	149	1,420	72	1,130	39

	Last	216	21	83	75	225	13	142	4
PAHs	**First**	482	53	773	25	330	12	453	14
	Last	71	5	88	5	58	10	80	4

Degradation of Individual Alkanes

High Concentration Experiment. Table S3 summarizes the first-order biodegradation coefficients for individual alkanes. At 25 °C, among all the compound monitores only n-C_{10} was biodegraded faster (-2.00 vs. -1.34 d^{-1}) with the addition of dispersant. Branched alkanes exhibited similar rates regardless of the presence of C9500, although higher variability among triplicates was observed in the oil alone samples (Fig. S1 A and B). At 5 °C, consistently higher rates for n-C_{10-27} were observed in the dispersed oil treatment when compared to the oil alone treatment. Also, no lag period for the biodegradation of branched alkanes occurred when C9500 was added, whereas an 8-day lag period occurred in the absence of dispersant.

Low Concentration Experiment. As depicted in Figs. S1-5 (panels C and D), only n-C_{10-16} was completely removed at both temperatures in the low concentration experiment. In this case,a more qualitative approach was used by comparing the disappearance time. At 25 °C in the low oil concentration experiment, n-C_{10} was degraded faster in the presence of dispersant, disappearing completely before day 2, whereas in the absence of C9500, its depletion was achieved only after day 8. The biodegradation of n-C_{10} was also accelerated when C9500 was present at 5 °C, as shown in Table S4 (-0.47 vs -0.63 d^{-1}). At both temperatures, branched alkanes were not degraded faster in the presence of dispersant, as shown in Table S4 and Fig. S1 C-D.

The major mechanism of uptake of water-insoluble substrates (i.e., alkanes) is generally recognized as direct interaction between microbes and the hydrophobic substance (Rojo, 2009; Wentzel et al., 2007) and the effects of surfactant on such process are inconclusive (Bredholt et al., 2002; Bruheim et al., 1999; Tang et al., 1998). Both conducive and inhibitory effects of dispersant on oil biodegradation have been reported (Lindstrom and Braddock, 2002; Prince et al., 2013; Venosa and Holder, 2007). In this study, C9500 exhibited similar effects on the biodegradation of alkanes in the high and low concentration experiments. Such effects included enhancement of biodegradation rates and shortening of lag periods. Rate enhancements were more notable in the high concentration experiment, whereas C9500 clearly shortened lag phases in the lower concentration tests.

The application of dispersants to an oil slick promotes the formation of small oil droplets by decreasing the interfacial tension between oil and water (Jasper et al., 1978; Li et al., 2009; Lunel, 1995). Consequently, the total interfacial area of oil droplets for microbes to interact with is increased. In the high concentration experiment, exposure of substrates to the microbes is enough that biodegradation can initiate soon after inoculation. In this case, dispersants assisted biodegradation mainly by increasing interfacial area for microbes to interact with oil. For the low concentration experiment, the observed long acclimation phase at both temperatures, especially in the absence of C9500, was possibly due to limited exposure of alkanes to the microorganisms in the beginning. Since the oil load, appearing as an iridescent sheen, is so low, the mixing energy in the flasks could be high enough to produce similar droplet size distribution in the oil alone and dispersed oil treatments. Thus, C9500 may have shortened the lag phase in the low concentration experiment by promoting the attachment of microbes to the oil droplet.

Total Aromatics Degradation

High Concentration Experiment. Fig. 5A-B presents total PAH biodegradation data for the high concentration experiment at both temperatures. Aromatics removals of 42 and 24% occurred by day 2 in the dispersed oil and the oil alone treatment, respectively. This difference in extent was significant ($p < 0.0001$), which indicates a positive effect of the dispersant. At 5 °C, the time for attaining maximum level of PAHs removal in non-dispersed treatment took twice as much time as in dispersed oil treatment 16 days vs. 8 days (solid symbols in Fig. 5B and 5A, respectively). The overall PAHs removals in the presence and absence of dispersant were 86% and 82%, respectively.

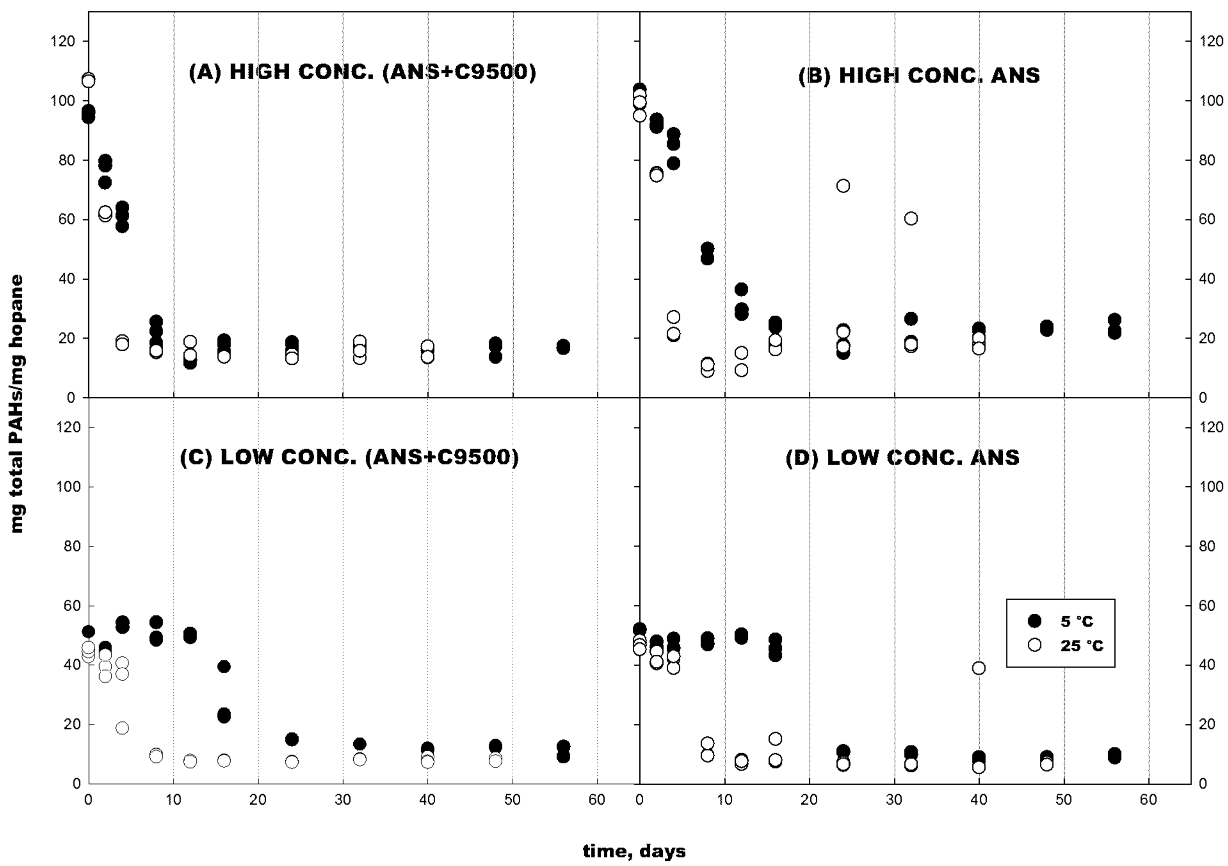


Figure 5. Biodegradation of hopane-normalized total PAHs at both temperatures in high concentration treatments (A, B) and low concentration treatments (C, D).

Low Concentration Experiment. As shown in Fig. 5C-D, when comparing the two low concentration treatments at 25 °C (open symbols), the only difference was in one replicate of dispersed oil on day 4, which had significantly lower total PAH concentration than the parallel diluted oil alone samples. At the high temperature (open symbols), the patterns of PAH degradation were similar in the absence and presence of C9500, regardless of initial concentration. The treatment without dispersant experienced higher variability. The lag period at the low temperature (closed symbols) was longer than at 25 °C; it lasted12 and 16 days for dispersed oil and oil alone, respectively. For the sampling event on day 16, the extent of PAH removal was 20 to 50% in the replicates of dispersed oil sample, while it was negligible in the treatment without dispersant.

Transport of compounds from non-aqueous phase to aqueous phase is often the most rate-limiting step in the biodegradation of PAHs. Surfactants can enhance the dissolution of PAHs by increasing interfacial area of oil droplet and subsequently increase the bioavailability of PAHs to microorganisms (Haritash and Kaushik, 2009; Mrozik et al., 2003). The effect of C9500 on the biodegradation of total PAHs was less pronounced in the low concentration experiment than in the high concentration experiment, because this effect was observed only in one or more replicates in a single sampling event. This finding is consistent with our previous assumption about low concentration experiment: droplet size distribution in the oil alone and dispersed oil treatments are similar. Dispersion in the oil alone microcosms might have been efficient enough even without the addition surfactant, considering the mixing energy was sufficient (Kaku, 2006) and the initial presence of oil was an iridescent rainbow-colored sheen. Clearly, the comparison between our low concentration dispersed oil samples and oil alone samples indicates that dispersants had less enhancing effect on the bio-uptake of PAHs after dilution. Nevertheless, most toxicity studies on dispersed oil concluded that the presence of dispersant increased environmental risk for aquatic organisms living in the water column (Milinkovitch et al., 2011; Ramachandran et al., 2004), which is possibly due to their relatively high concentration of oil and dispersant in the laboratory tests.

Individual Aromatics Degradation

High Concentration Experiment. A first-order model could be used to fit the biodegradation of the individual PAHs that had a negligible fraction persisting by the end of the high concentration experiment. At both temperatures, the biodegradation rates of naphthalene, phenanthrene, fluorine, and dibenzothiophene and their homologues in the high concentration experiment were consistantly higher in the presence of dispersant (Table S5). The greatest enhancement was observed with naphthalene at 25 °C, which was 2.9-fold higher than at 5 °C (-1.94 d^{-1} vs. -0.68 d^{-1}). The surfactant likely assisted the transfer of more soluble compounds from the oil phase to the aqueous phase through the formation of small oil droplets and the resultant increase in interfacial area. Because the bio-uptake of aromatics is mostly from aqueous phase (Haritash and Kaushik, 2009; Mrozik et al., 2003), C9500 promoted the biodegradation of PAHs by increasing their bioavailability in water.

Low Concentration Experiment. Among the low concentration individual PAHs, the time-varying concentration of specific aromatics could be fitted to a first-order kinetics model (rates shown in Table S6), and the results revealed reduced rates due to dilution (low vs. high), especially when C9500 was present (i.e. naphthalene: -0.36 d^{-1} v -1.94 d^{-1}). However, we could not fit a first-order model for the other PAH compounds in the low concentration experiments because of the long lag period and the immediate and nearly complete removal after biodegradation started. As mentioned before, C9500 acted less effectively on the biodegradation of total PAHs in the low concentration experiment, because different PAH concentrations in parallel dispersed oil and oil alone samples was observed only at one or more replicates in a single sampling event (25 °C: day 4, 5 °C: day 16). Nevertheless, C_4-naphthalene, $C_{2\text{-}4}$-phenanthrene, $C_{2\text{-}3}$-fluorene, and naphthobenzothiophene were removed at higher extent in the low rather than in the high concentration samples (Fig. S6). The increase in removal extent for the aforementioned aromatics were 6-14%, 4-47%, 14-54%, and 55-86% respectively. Zahed et al. (2010) also observed similar enhancement of crude oil removal extent in low oiling experiments. In the low concentration experiment, the starting PAH concentrations were equal to or below the remaining residual found in the high concentration experiment, but the cultures were able to degrade the aromatic compounds to an even lower level, as shown in Table 1. The reasons are a combination of the following: (1) the alkylated structure of these compounds led to less aqueous dissolution and less susceptibility to microbial attack; (2) their aqueous uptake was primarily diffusion, for which neither energized membrane nor adenosine triphosphate was essential (Bateman et al., 1986). Taking C_2-phenanthrene for example, it was fully degraded in the low concentration experiment, whereas its removal extent ranged from 66% to 94% when the initial oil concentration was high. The enhancement in the extent of removal under diluted conditions was more remarkable at low temperature, which contributed to our conclusion that solubility was the limiting factor for those compounds to be biodegraded. Whether oil concentration is high or low, pyrene, chrysene and naphthobenzothiophene homologues persisted until the last sampling event at both temperatures, as depicted in Figs. S7 and S8. The heavy PAHs, such as chrysene, are likely to be retained on a beach for several years, according to Yin et al. (2015), who conducted research that monitors the submerged oil mats and surface residual oil balls off Alabama's beach affected by the 2010 DWH incident.

ACKNOWLEDGMENTS

We thank Jan Kurtz and Diane Yates from EPA's Gulf Ecology Division (GED) at Gulf Breeze, FL, who collected the water samples in the GOM and performed the enrichments and provided them for our experiments. The research was a product of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory (NRMRL) and was partially funded by EPA, NRMRL, Cincinnati, OH, under Pegasus Technical Services, Inc. Contract EP-C-11-006.

REFERENCES

2007. U.S. Environmental Protection Agency, EPA 8270D Semivolatile organic compounds by gas chromatography/mass spectrometry (GC/MS), 3rd. ed, Washington, D.C.

API, 2013. Net Environmental Benefit Analysis for effective oil spill preparedness and response. 2013. http://www.api.org/~/media/Files/EHS/Clean_Water/Oil_Spill_Prevention/NEBA/NEBA-Net-Environmental-Benefit-Analysis-July-2013.pdf.

Batchu, S.R., Ramirez, C.E., Gardinali, P.R., 2014. Stability of dioctyl sulfosuccinate (DOSS) towards hydrolysis and photodegradation under simulated solar conditions. Sci. Total. Environ. 481, 260-265.

Bateman, J.N., Speer, B., Feduik, L., Hartline, R.A., 1986. Naphthalene association and uptake in Pseudomonas putida. J. Bacteriol. 166, 155-161.

Brakstad, O.G., Nordtug, T., Throne-Holst, M., 2015. Biodegradation of dispersed Macondo oil in seawater at low temperature and different oil droplet sizes. Marine pollution bulletin 93, 144-152.

Bredholt, H., Bruheim, P., Potocky, M., Eimhjellen, K., 2002. Hydrophobicity development, alkane oxidation, and crude-oil emulsification in a Rhodococcus species. Can. J. Microbiol. 48, 295-304.

Bruheim, P., Bredholt, H., Eimhjellen, K., 1999. Effects of surfactant mixtures, including Corexit 9527, on bacterial oxidation of acetate and alkanes in crude oil. Appl. Environ. Microbiol. 65, 1658-1661.

Campo, P., Venosa, A.D., Suidan, M.T., 2013. Biodegradability of Corexit 9500 and dispersed South Louisiana crude oil at 5 and 25 degrees C. Environ. Sci. Technol. 47, 1960-1967.

D7730−11, A., 2011. Standard Test Method for Determination of Dioctyl Sulfosuccinate in Sea Water by Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS). ASTM International 2011. ASTM International.

Gray, J.L., Kanagy, L.K., Furlong, E.T., Kanagy, C.J., McCoy, J.W., Mason, A., Lauenstein, G., 2014. Presence of the Corexit component dioctyl sodium sulfosuccinate in Gulf of Mexico waters after the 2010 Deepwater Horizon oil spill. Chemosphere 95, 124-130.

Haritash, A.K., Kaushik, C.P., 2009. Biodegradation Aspects of Polycyclic Aromatic Hydrocarbons (PAHs): A review. J. Hazard. Mater. 169, 1-15.

Jasper, W.L., Kim, T.L., Wilson, M.P., 1978. Droplet size distributions in a treated oil–water system., in: McCarthy, L.T., Lindblom, G.P., Walter, H.F. (Eds.), Chemical Dispersants for the Control of Oil Spills. American Society for Testing and Materials, Philadelphia, PA.

Kaku, V.J., Boufadel, M.C., Venosa, A.D., 2006. Evaluation of mixing energy in laboratory flasks used for dispersant effectiveness testing. J. Environ. Eng. Div. ASCE 132, 93-101.

Kujawinski, E.B., Kido Soule, M.C., Valentine, D.L., Boysen, A.K., Longnecker, K., Redmond, M.C., 2011. Fate of dispersants associated with the deepwater horizon oil spill. Environ. Sci. Technol. 45, 1298-1306.

Lee, K., Nedwed, T., Prince, R.C., Palandro, D., 2013. Lab tests on the biodegradation of chemically dispersed oil should consider the rapid dilution that occurs at sea. Mar. Pollut. Bull. 73, 314-318.

Li, Z., Lee, K., King, T., Boufadel, M.C., Venosa, A.D., 2009. Evaluating Chemical Dispersant Efficacy in an Experimental Wave Tank: 2—Significant Factors Determining In Situ Oil Droplet Size Distribution. 26, 1407-1418.

Lindstrom, J.E., Braddock, J.F., 2002. Biodegradation of petroleum hydrocarbons at low temperature in the presence of the dispersant Corexit 9500. Mar. Pollut. Bull. 44, 739-747.

Lunel, T., 1995. Understanding the mechanism of dispersion through oil droplet size measurements at sea., in: P. Lane (Ed.), The Use of Chemicals in Oil Spill Response. American Society for Testing and Materials, Philadelphia, PA.

Milinkovitch, T., Kanan, R., Thomas-Guyon, H., Le Floch, S., 2011. Effects of dispersed oil exposure on the bioaccumulation of polycyclic aromatic hydrocarbons and the mortality of juvenile Liza ramada. Sci. Total. Environ. 409, 1643-1650.

Mrozik, A., Piotrowska-Seget, Z., Labuzek, S., 2003. Bacterial Degradation and Bioremediation of Polycyclic Aromatic Hydrocarbons. Pol. J. Environ. Stud. 12, 15-25.

Operational Science Advisory Team, 2010. Summary report for sub-sea and sub-surface oil and dispersant detection: sampling and monitoring. Prepared for Paul F. Zukunft, U.S. Coast Guard.

Prince, R.C., 2015. Oil spill dispersants: boon or bane? Environmental science & technology 49, 6376−6384.

Prince, R.C., Elmendorf, D.L., Lute, J.R., Hsu, C.S., Halth, C.E., Senius, J.D., Dechert, G.J., Douglas, G.S., Butler, E.L., 1994. 17α(H),21β(H)-hopane as a conserved internal marker for estimating the blodegradation of crude oil. Environ. Sci. Technol. 28, 142-145.

Prince, R.C., McFarlin, K.M., Butler, J.D., Febbo, E.J., Wang, F.C., Nedwed, T.J., 2013. The primary biodegradation of dispersed crude oil in the sea. Chemosphere 90, 521-526.

Ramachandran, S.D., Hodson, P.V., Khan, C.W., Lee, K., 2004. Oil dispersant increases PAH uptake by fish exposed to crude oil. Ecotox. Environ. Safe. 59, 300-308.

Rojo, F., 2009. Degradation of Alkanes by Bacteria. Environ. Microbiol. 11, 2477-2490.

Spotte, S., Adams, G., Bubucis, P.M., 1984. GP2 medium is an synthetic seawater for culture or maintenance of marine organisms. . Zoo Biol. 3, 229-240.

Tang, W.C., White, J.C., Alexander, M., 1998. Utilization of sorbed compounds by microorganisms specifically isolated for that purpose. Appl. Microbiol. Biotechnol. 49, 117-121.

Venosa, A.D., Holder, E.L., 2007. Biodegradability of dispersed crude oil at two different temperatures. Mar. Pollut. Bull. 54, 545-553.

Wentzel, A., Ellingsen, T.E., Kotlar, H.K., Zotchev, S.B., Throne-Holst, M., 2007. Bacterial metabolism of long-chain n-alkanes. Appl. Microbiol. Biotechnol. 76, 1209-1221.

Word, J.Q., Clark, J.R., Word, L.S., 2014. Comparison of the Acute Toxicity of Corexit 9500 and Household Cleaning Products. Human Ecol. Risk Assess. 21, 19.

Yin, F., John, G.F., Hayworth, J.S., Clement, T.P., 2015. Long-term monitoring data to describe the fate of polycyclic aromatic hydrocarbons in Deepwater Horizon oil submerged off Alabama's beaches. The Science of the total environment 508, 46-56.

Zahed, M.A., Aziz, H.A., Isa, M.H., Mohajeri, L., 2010. Effect of initial oil concentration and dispersant on crude oil biodegradation in contaminated seawater. Bull. Environ. Contam. Toxicol. 84, 438-442.

*Supporting Information

Biodegradability of Different Initial Concentrations of Alaska North Slope Crude Oil Dispersed with Corexit C9500

Mobing Zhuang[1], Gulizhaer Abulikemu[2], Pablo Campo[3], William Platten III[4], Makram T. Suidan[5]*, Albert D. Venosa (retired)[4]and Robyn N. Conmy[4]

1 Department of Biomedical, Chemical and Environmental Engineering, University of Cincinnati, 2901 Woodside Drive, Cincinnati, OH 45221, USA

2 Pegasus Technical Services Inc., 46 E Hollister St, Cincinnati, OH 45219 USA

3 Cranfield Water Science Institute, Cranfield University, Cranfield, Beds, MK43 0AL, UK

4 U.S. Environmental Protection Agency, NRMRL, 26 W. MLK Drive Cincinnati, OH, 45268, USA

5 Faculty of Engineering and Architecture, American University of Beirut, Bechtel Engineering Bldg. - 3rd flr. - Room 308 P.O. Box: 11-0236 Riad El Solh 1107 2020, Beirut, Lebanon

*Corresponding author: Makram T. Suidan
Tel: 00961-1-347952
Fax: 00961-1-744462
E-mail address: msuidan@aub.edu.lb

Table S1. Summary of Experimental Layout for High Concentration Experiment.

Test	Temperature	Treatment	Sampling Events	Sample Replicates	Total Experimental Units (EU)
1	5 °C	C9500 alone	11	3	33
2	5 °C	ANS dispersed by C9500	11	3	33
3	5 °C	alone	11	3	33
4	5 °C	Killed ANS control	1	3	3
5	5 °C	Killed C9500 control	11	3	33
6	5 °C	Killed ANS+C9500 control	11	3	33
				Subtotal EU's	**168**
7	25 °C	C9500 alone	9	3	27
8	25 °C	ANS dispersed by C9500	9	3	27
9	25 °C	ANS alone	9	3	27
10	25 °C	Killed ANS control	1	3	3
11	25 °C	Killed C9500 control	9	3	27
12	25 °C	Killed ANS+ C9500 control	9	3	27
				Subtotal EU's	**138**
		Total EU's for High Concentration Experiment			**306**

Table S2. Summary of Experimental Layout for Low Concentration Experiment.					
Test	**Temperature**	**Treatment**	**Sampling Events**	**Sample Replicates**	**Total Experimental Units (EU)**
13	5 °C	C9500 alone	11	3	33
14	5 °C	ANS+C9500	11	3	33
15	5 °C	ANS alone	11	3	33
16	5 °C	Killed ANS control	1	3	3
17	5 °C	Killed C9500 control	11	3	33
18	5 °C	Killed (ANS+C9500) control	11	3	33
19	5 °C	Killed (ANS+C9500) +Protease	6	3	18
				Subtotal EU's	**186**
20	25 °C	C9500 alone	10	3	30
21	25 °C	ANS+C9500	10	3	30
22	25 °C	ANS alone	10	3	30
23	25 °C	Killed ANS control	1	3	3
24	25 °C	Killed C9500 control	10	3	30
25	25 °C	Killed (ANS+C9500) control	10	3	30
26	25 °C	Killed (ANS+C9500) +Protease	6	3	18
				Subtotal EU's	**181**
		Total EU's for Low Concentration Experiment			**357**

Table S3. First-order biodegradation rate coefficients and standard deviations (sd) of individual alkanes in the high concentration experiment.

Compound	5 °C ANS alone		25 °C ANS alone		5 °C ANS+C9500		25 °C ANS+C9500	
	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})
C10	0.19	0.02	1.34	0.18	0.63	0.03	2.00	0.34
C11	0.15	0.01	1.16	0.15	0.40	0.02	1.30	0.09
C12	0.12	0.01	1.02	0.14	0.29	0.03	0.96	0.06
C13	0.11	0.01	0.94	0.14	0.27	0.03	0.91	0.05
C14	0.11	0.01	0.92	0.14	0.25	0.03	0.82	0.04
C15	0.11	0.01	0.95	0.14	0.24	0.03	0.84	0.05
C16	0.11	0.01	1.01	0.15	0.24	0.03	0.92	0.05
C17	0.11	0.01	1.08	0.16	0.24	0.03	0.97	0.06
PR	0.15	0.03	0.45	0.11	0.07	0.01	0.39	0.04
C18	0.11	0.01	1.06	0.14	0.22	0.02	0.96	0.05
PH	0.15	0.03	0.46	0.12	0.08	0.01	0.43	0.04
C19	0.11	0.01	1.05	0.14	0.22	0.02	0.97	0.06
C20	0.11	0.01	0.99	0.14	0.21	0.02	0.93	0.05
C21	0.10	0.01	0.97	0.14	0.20	0.02	0.91	0.05
C22	0.10	0.01	0.88	0.13	0.19	0.02	0.84	0.04
C23	0.09	0.01	0.84	0.13	0.18	0.02	0.79	0.04
C24	0.09	0.01	0.84	0.14	0.17	0.02	0.79	0.04
C25	0.09	0.01	0.81	0.13	0.15	0.02	0.81	0.03
C26	0.08	0.01	0.81	0.14	0.12	0.02	0.78	0.04
C27	0.08	0.01	0.74	0.13	0.11	0.01	0.71	0.05
C28	0.12	0.02	0.75	0.12	0.12	0.02	0.60	0.09
C29	0.12	0.02	0.81	0.15	0.12	0.02	0.81	0.07
C30	0.10	0.01	0.83	0.14	0.12	0.02	0.74	0.04
C31	0.09	0.01	0.81	0.14	0.09	0.01	0.61	0.05
C32	0.10	0.01	0.81	0.14	0.09	0.01	0.60	0.06
C33	0.09	0.01	0.68	0.09	0.07	0.01	0.56	0.06
C34	0.08	0.01	0.60	0.09	0.05	0.01	0.54	0.05
C35	0.07	0.01	0.53	0.09	0.04	0.01	0.58	0.04

NA: Rate not calculated because the biodegradation of noted compounds did not follow first order kinetics.

Table S4. First-order biodegradation rate coefficients and standard deviations (sd) of individual alkanes in low concentration experiment.

Compound	5 °C ANS alone		25 °C ANS alone		5 °C ANS+C9500		25 °C ANS+C9500	
	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})
C10	0.47	0.03	0.93	0.16	0.63	0.04	NA1	NA1
C11	0.25	0.02	0.57	0.07	0.25	0.03	0.47	0.02
C12	0.20	0.01	0.38	0.06	0.23	0.02	0.24	0.03
C13	0.18	0.01	0.42	0.06	0.21	0.02	NA2	NA2
C14	0.13	0.01	0.28	0.04	0.15	0.01	NA2	NA2
C15	0.14	0.01	0.35	0.04	0.15	0.01	NA2	NA2
C16	0.14	0.01	0.37	0.04	0.15	0.02	NA2	NA2
C17	0.13	0.01	0.36	0.04	NA2	NA2	NA2	NA2
PR	NA2	NA2	0.04	0.01	NA2	NA2	NA2	NA2
C18	NA2	NA2	0.35	0.04	NA2	NA2	NA2	NA2
PH	NA2	NA2	0.03	0.01	NA2	NA2	NA2	NA2
C19	NA2	NA2	0.32	0.04	NA2	NA2	NA2	NA2
C20	NA2	NA2	0.30	0.04	NA2	NA2	NA2	NA2
C21	NA2	NA2	0.29	0.04	NA2	NA2	NA2	NA2
C22	NA2	NA2	0.17	0.03	NA2	NA2	NA2	NA2
C23	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C24	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C25	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C26	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C27	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C28	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C29	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C30	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C31	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C32	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C33	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C34	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2
C35	NA2	NA2	NA2	NA2	NA2	NA2	NA2	NA2

NA1: Rate not calculated because of excessively rapid removal after acclimation.
NA2: Rate not calculated because noted compounds were persisted during the experiment.

Table S5. First-order degradation rate coefficients and standard deviations (sd) of individual PAHs in high concentration experiment.

Compound	5 °C ANS alone		25 °C ANS alone		5 °C ANS+C9500		25 °C ANS+C9500	
	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})
nap	0.44	0.04	0.68	0.05	0.71	0.02	1.94	0.02
C1-nap	0.23	0.02	0.60	0.04	0.41	0.03	1.84	0.04
C2-nap	0.17	0.02	0.38	0.07	0.26	0.02	0.61	0.03
C3-nap	0.27	0.02	0.35	0.10	0.20	0.02	0.40	0.05
C4-nap	0.13	0.02	0.29	0.10	0.16	0.02	0.35	0.05
phe	0.19	0.01	0.37	0.09	0.26	0.02	0.46	0.05
C1-phe	0.12	0.01	0.34	0.12	0.19	0.02	0.37	0.06
C2-phe	0.05	0.01	0.21	0.07	0.19	0.03	0.27	0.04
C3-phe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C4-phe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
flu	0.19	0.02	0.37	0.10	0.26	0.02	0.44	0.05
C1-flu	0.15	0.02	0.35	0.11	0.21	0.02	0.39	0.06
C2-flu	0.05	0.01	0.20	0.07	0.11	0.01	0.27	0.04
C3-flu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
dbt	0.25	0.01	0.43	0.08	0.44	0.02	0.77	0.03
C1-dbt	0.13	0.01	0.32	0.10	0.22	0.02	0.41	0.04
C2-dbt	0.04	0.01	0.17	0.06	0.11	0.01	0.26	0.04
C3-dbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
nbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1-nbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2-nbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3-nbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pyr*	--	--	--	--	--	--	--	--
C1-pyr	0.00	0.00	0.00	NA	NA	0.00	NA	NA
C2-pyr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C4-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NA: Rate not calculated because noted compounds were persisted during the experiment.
* Not detected in any samples.

Table S6. First-order degradation rate coefficients and standard deviations (sd) of individual PAHs in low concentration experiment.

Compound	5 °C ANS alone		25 °C ANS alone		5 °C ANS+C9500		25 °C ANS+C9500	
	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})	rate (d^{-1})	sd (d^{-1})
nap	NA	NA	0.29	0.05	0.43	0.09	0.36	0.03
C1-nap	NA	NA	0.24	0.03	0.44	0.09	0.28	0.03
C2-nap	NA	NA	0.17	0.04	0.40	0.09	0.21	0.04
C3-nap	NA	NA	0.18	0.04	0.31	0.06	0.20	0.04
C4-nap	NA	NA	0.13	0.03	0.15	0.02	0.14	0.02
phe	NA	NA	NA	NA	NA	NA	0.19	0.03
C1-phe	NA	NA	NA	NA	0.18	0.03	0.20	0.03
C2-phe	0.25	0.01	0.14	0.03	0.11	0.01	NA	NA
C3-phe	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00
C4-phe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
flu	NA	NA	NA	NA	0.29	0.06	NA	NA
C1-flu	NA	NA	NA	NA	0.15	0.02	0.00	0.00
C2-flu	0.29	0.03	0.14	0.03	0.21	0.01	0.00	0.00
C3-flu	0.02	0.00	0.03	0.00	0.00	0.00	0.02	0.00
dbt	NA	NA	0.00	0.00	0.31	0.11	0.00	0.00
C1-dbt	NA	NA	NA	NA	0.23	0.05	0.29	0.06
C2-dbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3-dbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
nbt	0.00	0.00	NA	NA	0.00	0.00	0.31	0.11
C1-nbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2-nbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3-nbt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pyr*	--	--	--	--	--	--	--	--
C1-pyr	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.07
C2-pyr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C4-cry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NA: Rate not calculated because of excessively rapid removal after acclimation.
*Not detected in any samples.

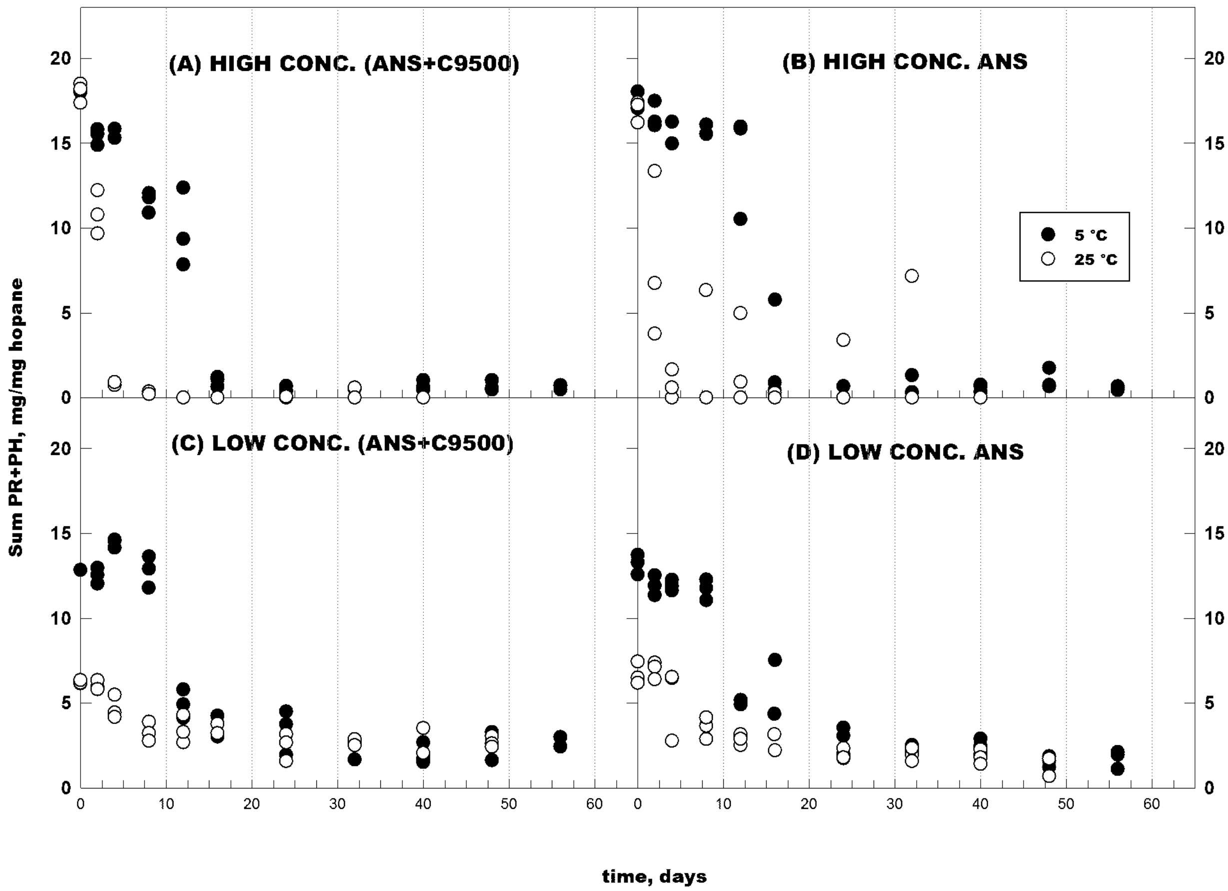


Figure S1. Biodegradation of branched alkanes in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C. High concentration treatments are in panel A and B, whereas low concentration treatments are in panels C and D.

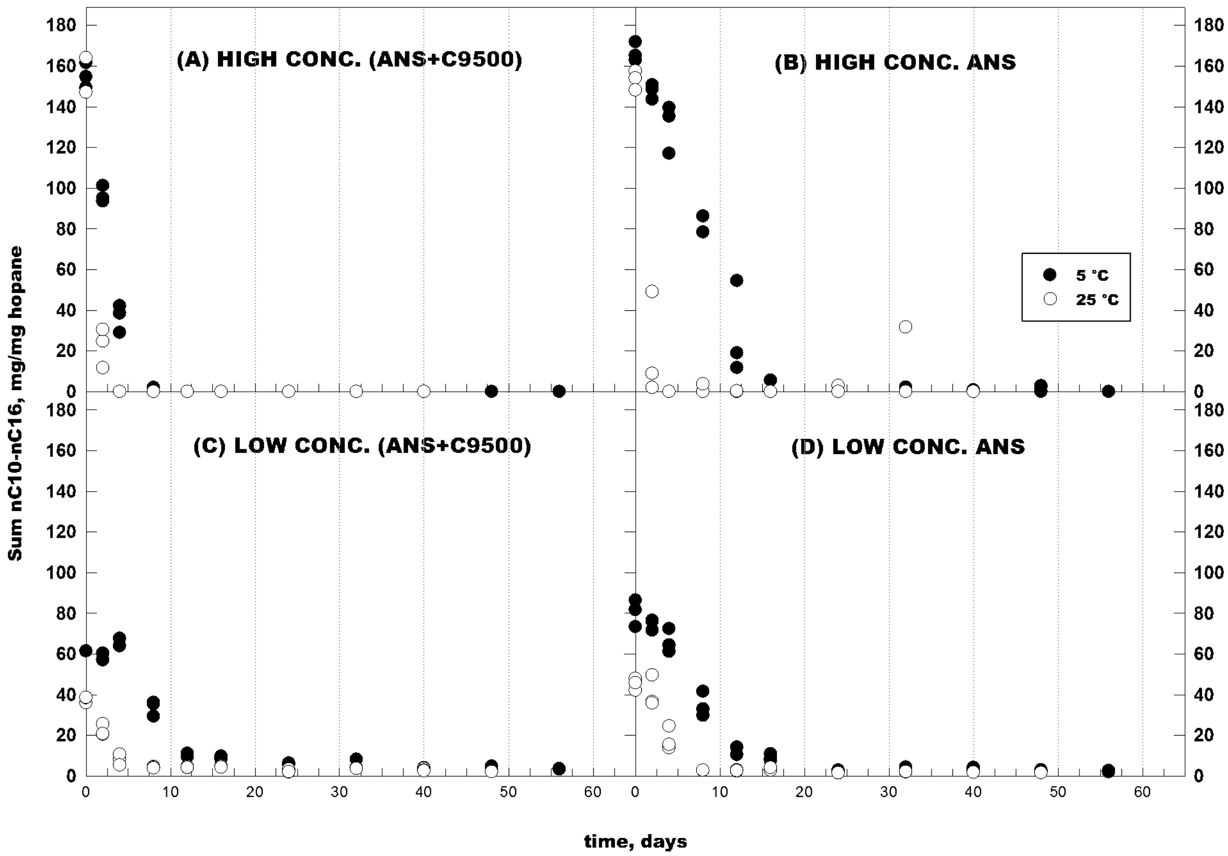


Figure S2. Biodegradation of n-alkanes (nC10-nC16) in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C. High concentration treatments are in panel A and B, whereas low concentration treatments are in panels C and D.

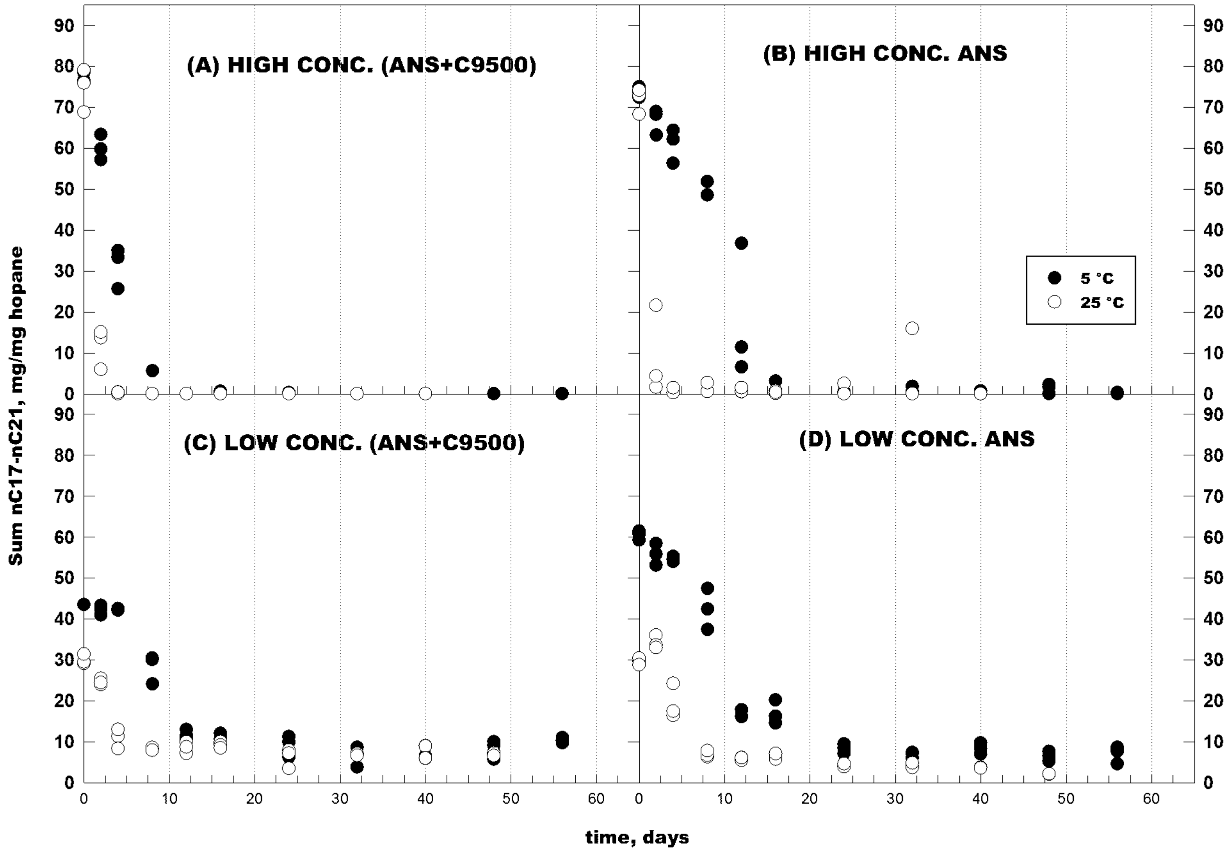


Figure S3. Biodegradation of n-alkanes (nC17-nC21) in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C. High concentration treatments are in panel A and B, whereas low concentration treatments are in panels C and D.

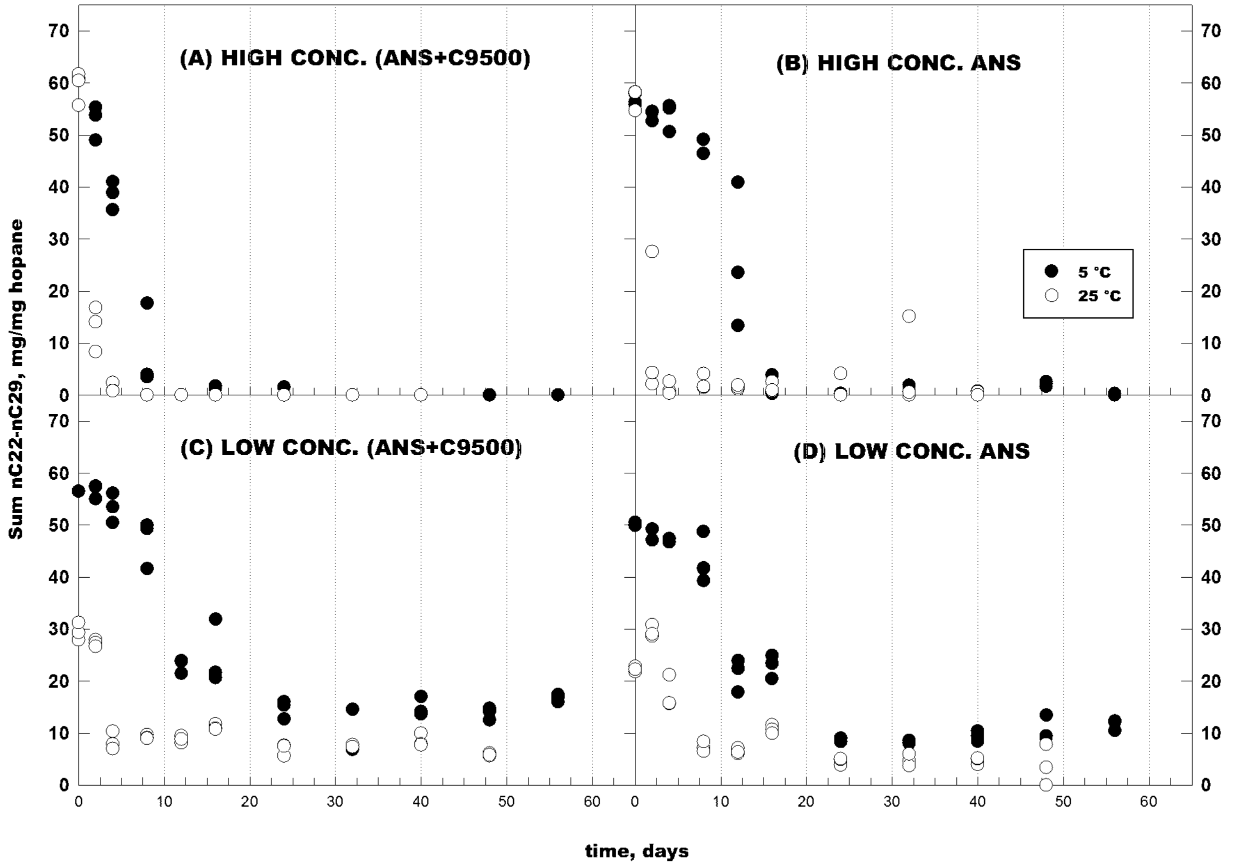


Figure S4. Biodegradation of n-alkanes (nC22-nC29) in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C. High concentration treatments are in panel A and B, whereas low concentration treatments are in panels C and D.

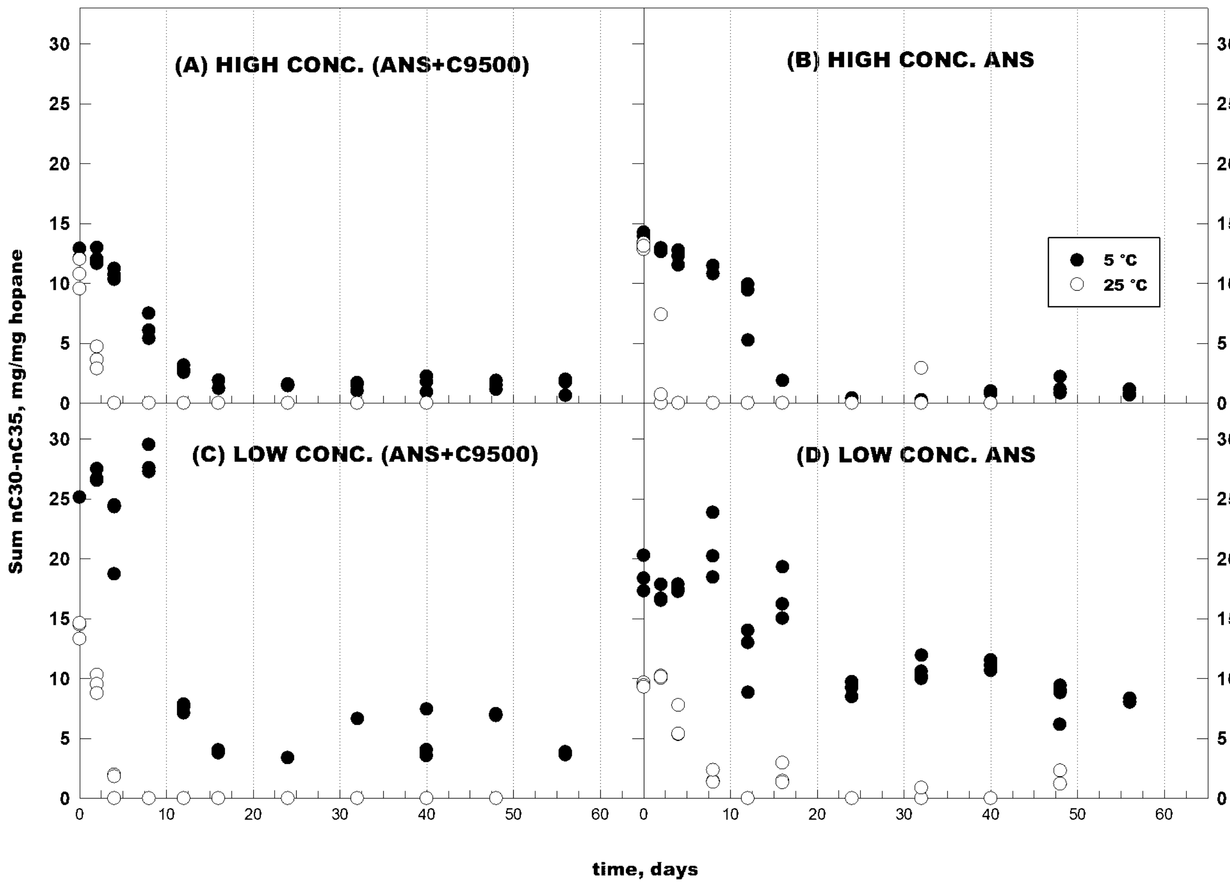


Figure S5. Biodegradation of n-alkanes (nC30-nC35) in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C. High concentration treatments are in panel A and B, whereas low concentration treatments are in panels C and D.

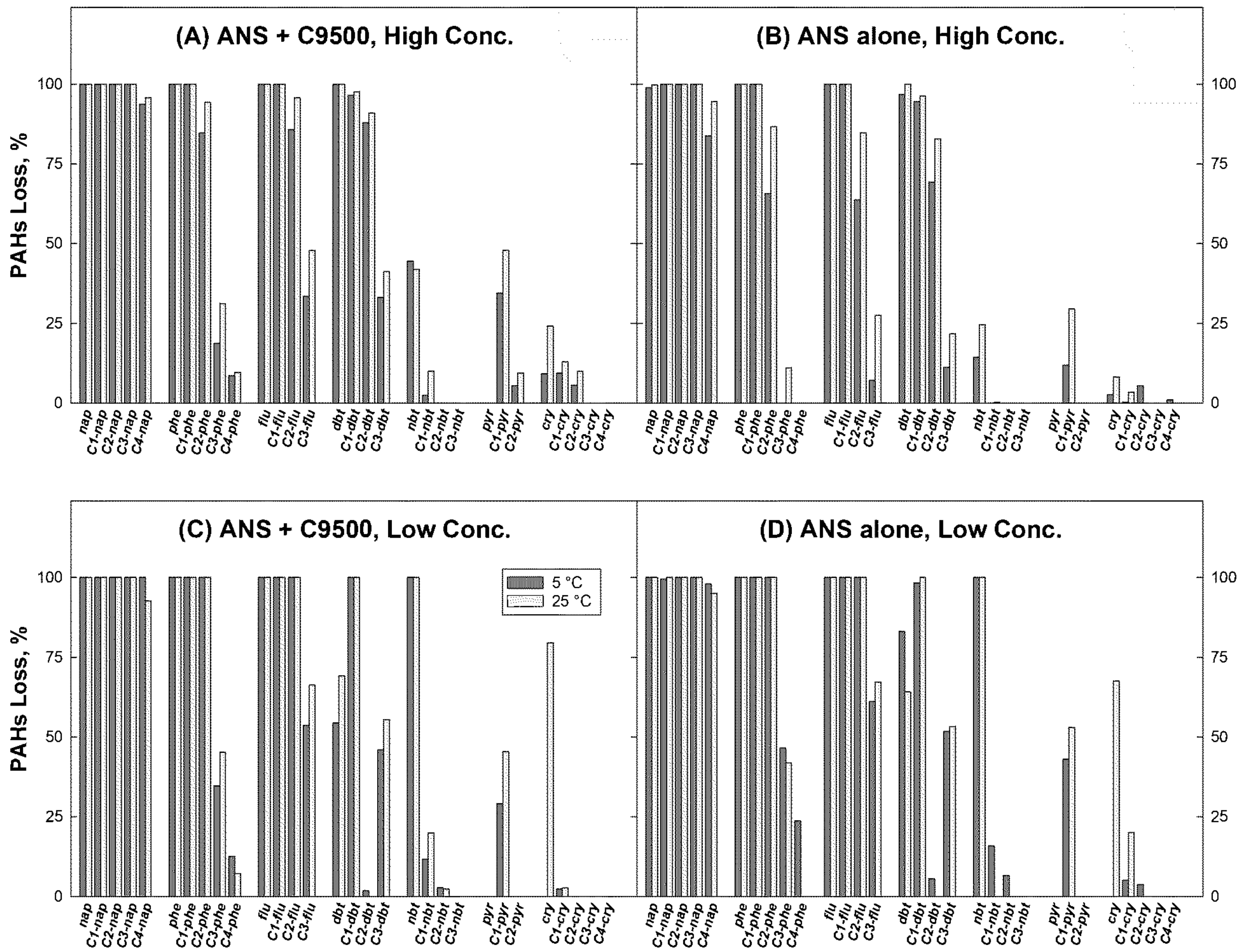


Figure S6. Loss percentage of individual PAH in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C in high concentration (A, B) and low concentration (C, D) experiment.

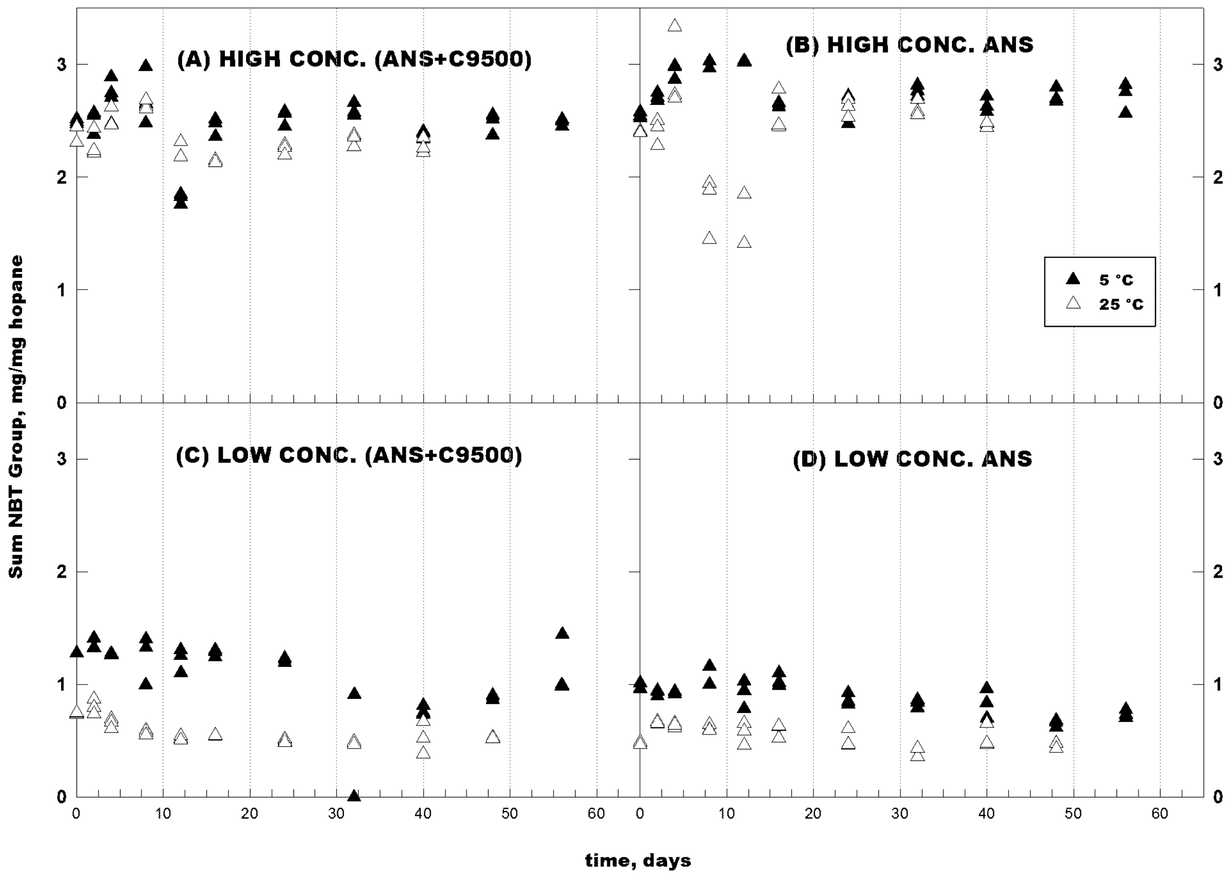


Figure S7. Biodegradation of naphthobenzothiophene homologues in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C. High concentration treatments are in panel A and B, whereas low concentration treatments are in panels C and D.

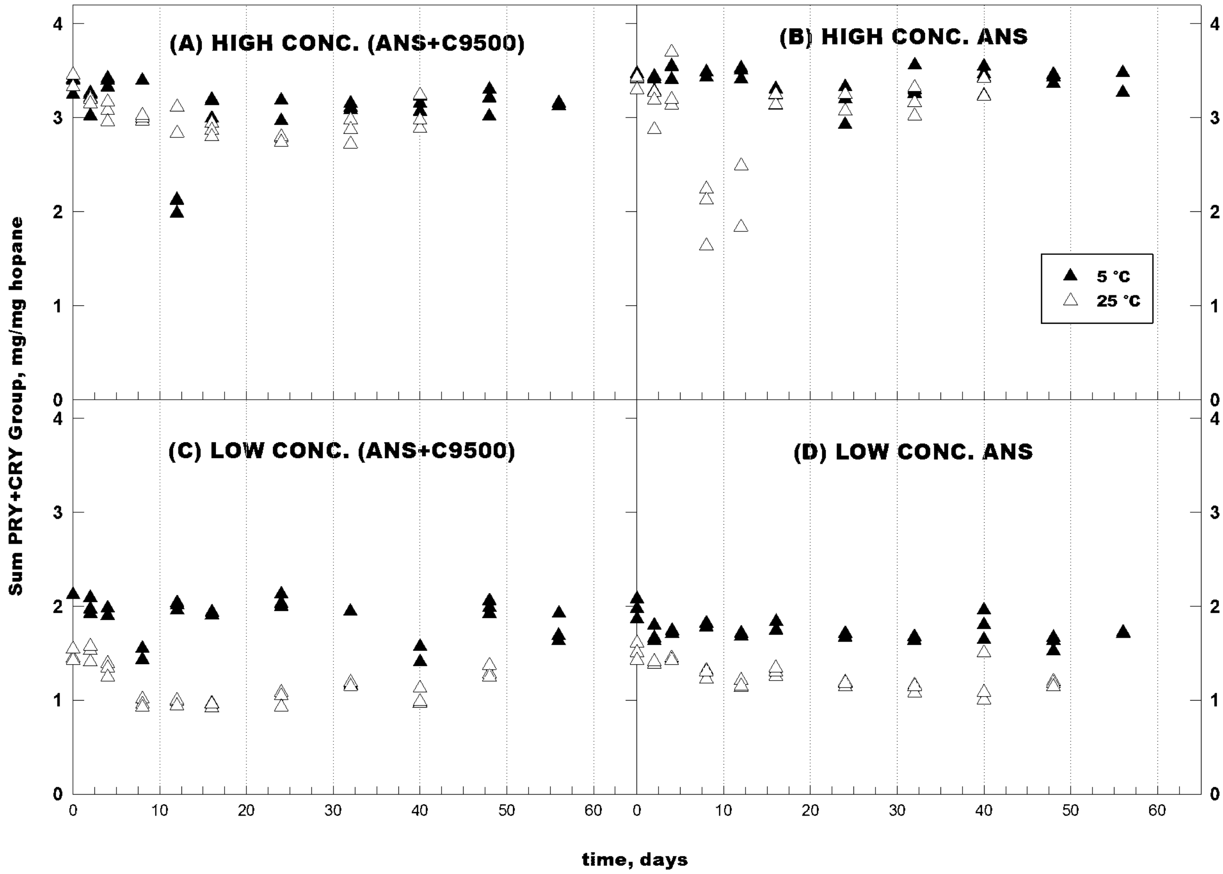


Figure S8. Biodegradation of pyrene homologues + chrysene homologues in the presence (A, C) and absence (B, D) of C9500 at 5 °C and 25 °C. High concentration treatments are in panel A and B, whereas low concentration treatments are in panels C and D.

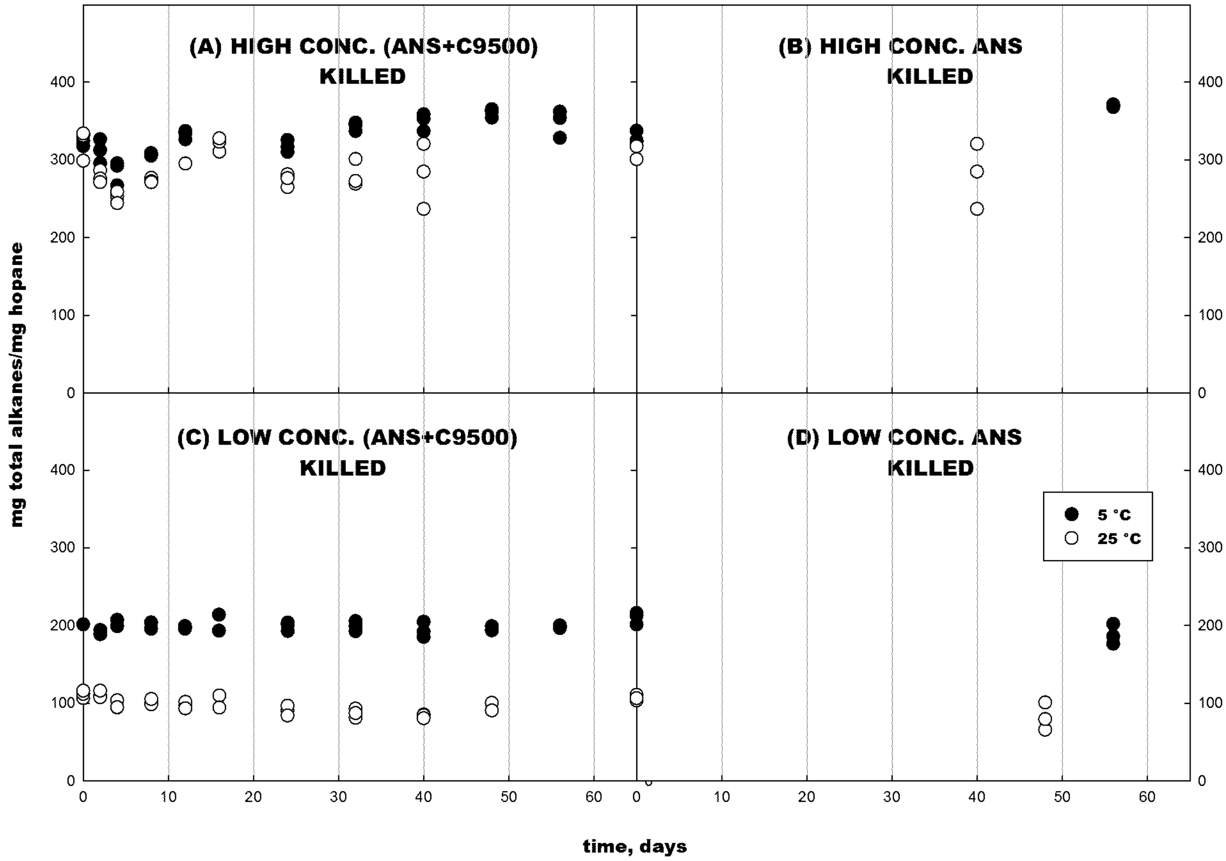


Figure S9. Biodegradation of hopane-normalized total alkanes at both temperatures in high concentration treatments (A, B) and low concentration treatments (C, D) in killed control samples.

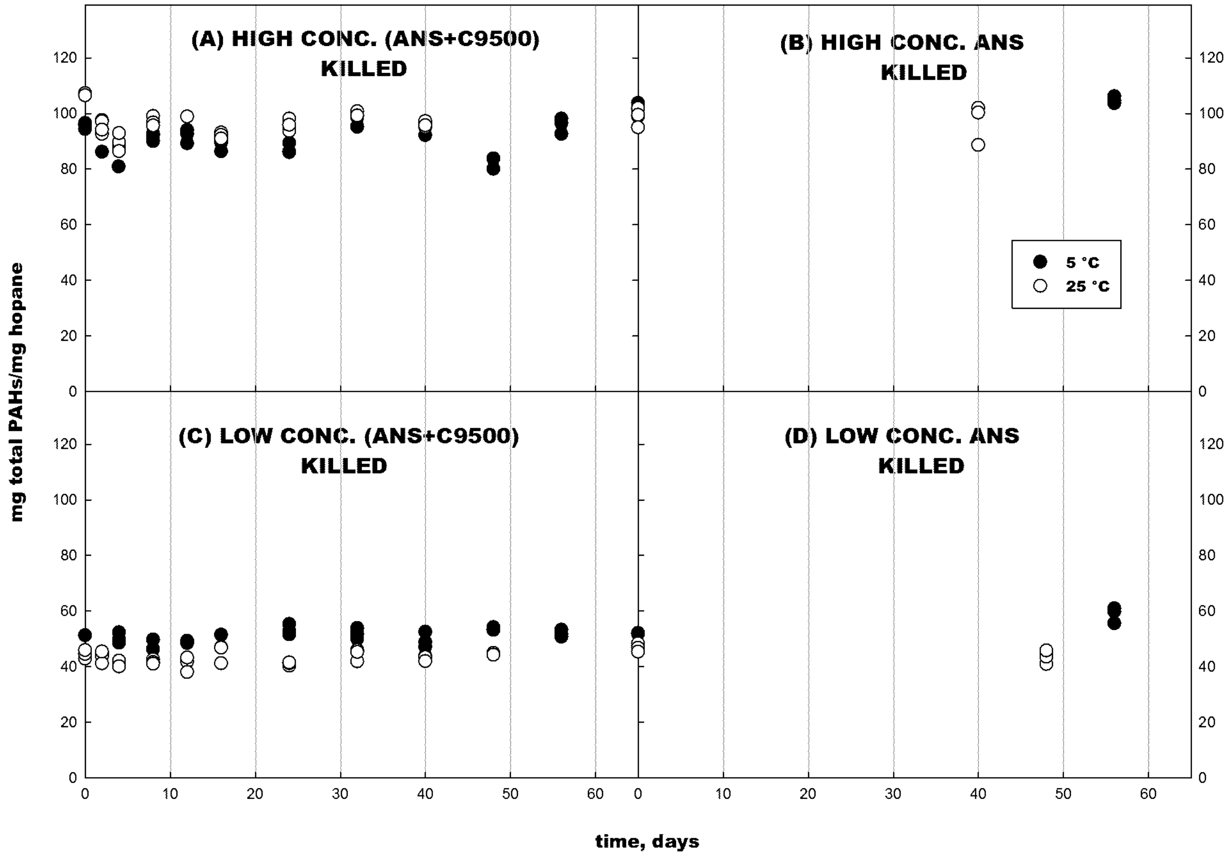


Figure S10. Biodegradation of hopane-normalized total PAHs at both temperatures in high concentration treatments (A, B) and low concentration treatments (C, D) in killed control samples.

dation of branched alkanes in the presence and absence of C9500 at 5 °C and 25 °C. (Hopane Normalize

	Low Conc.				High Conc.
Time	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS	5 °C (ANS+C9500)
0	12.84	13.73	6.15	6.48	18.05
0	N/A	13.28	6.18	6.18	18.00
0	N/A	12.57	6.34	7.44	18.14
2	12.56	11.91	5.93	7.37	15.53
2	12.03	11.35	6.34	7.12	14.88
2	12.96	12.51	5.81	6.39	15.82
4	14.56	12.25	5.48	6.46	15.84
4	14.62	11.90	4.42	6.53	15.30
4	14.14	11.62	4.16	2.76	15.30
8	11.77	11.05	3.88	3.64	12.05
8	12.91	12.27	3.22	4.13	10.91
8	13.63	11.76	2.76	2.87	11.79
12	5.78	5.17	2.67	2.51	12.34
12	4.12	4.96	4.30	3.14	7.84
12	4.91	4.93	3.28	2.87	9.34
16	4.24	7.50	3.76	3.13	1.20
16	3.21	4.34	3.20	3.16	0.64
16	3.01	7.56	3.21	2.20	1.07
24	1.94	3.06	1.57	1.73	0.68
24	4.49	3.53	3.15	2.33	0.36
24	3.73	1.98	2.66	1.77	0.42
32	2.71	1.58	2.86	1.92	0.51
32	1.66	2.12	2.50	1.57	0.56
32	N/A	2.51	N/A	2.34	0.52
40	2.67	1.99	3.51	2.26	0.63
40	1.74	2.45	2.02	1.78	1.02
40	1.51	2.89	2.05	1.40	0.45
48	3.07	1.58	3.03	1.71	0.56
48	1.61	1.85	2.61	0.68	0.47
48	3.28	1.20	2.41	N/A	1.02
56	2.46	2.10	N/A	N/A	0.73
56	2.99	1.10	N/A	N/A	0.47
56	2.49	1.94	N/A	N/A	0.69

nce of C9500 at 5 °C and 25 °C. (Hopane Normalized)		
High Conc.		
5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
17.04	17.37	17.39
18.04	18.50	17.25
17.25	18.19	16.21
17.48	10.80	3.76
16.25	12.21	6.75
16.05	9.67	13.36
16.26	0.74	0.00
14.98	0.73	0.59
16.26	0.91	1.66
N/A	0.36	0.00
15.53	0.35	0.00
16.09	0.20	6.35
15.97	0.00	0.92
10.52	0.00	0.00
15.85	N/A	4.96
0.89	0.00	0.27
0.43	0.00	0.00
5.77	0.00	0.00
0.67	0.00	3.37
0.00	0.00	0.00
0.00	0.05	0.00
1.32	0.00	7.16
0.00	0.58	0.00
0.30	0.00	0.00
0.75	0.00	0.00
0.33	0.00	0.00
0.67	0.00	0.00
0.65	N/A	N/A
0.74	N/A	N/A
1.74	N/A	N/A
0.66	N/A	N/A
0.57	N/A	N/A
0.44	N/A	N/A

on of n-alkanes (nC10-nC16) in the presence and absence of C9500 at 5 °C and 25 °C. (Hopane Normaliz

	Low Conc.				High Conc.
Time	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS	5 °C (ANS+C9500)
0	61.42	81.75	35.98	42.14	154.75
0	N/A	86.45	38.42	47.85	149.36
0	N/A	73.37	38.57	45.80	161.58
2	60.36	76.19	20.48	49.55	95.06
2	57.00	71.63	25.63	36.51	93.54
2	57.32	76.48	20.79	35.84	101.23
4	67.71	72.43	8.22	13.85	42.12
4	66.97	61.22	10.65	15.46	28.97
4	63.69	64.39	5.39	24.54	38.40
8	29.35	32.97	4.63	2.75	1.95
8	35.43	41.65	4.13	2.73	0.00
8	36.18	29.92	3.90	2.83	0.00
12	11.10	10.54	4.06	2.92	0.00
12	9.73	14.21	4.58	2.45	0.00
12	9.44	11.76	4.13	2.64	0.00
16	9.74	8.37	4.88	3.03	0.00
16	8.86	7.68	4.78	2.85	0.00
16	8.41	10.88	4.32	4.13	0.00
24	2.03	2.90	1.90	1.66	0.00
24	6.34	2.62	3.29	1.51	0.00
24	5.78	2.87	2.09	1.52	0.00
32	8.19	4.36	4.00	2.23	0.00
32	4.11	3.95	3.66	1.96	0.00
32	N/A	3.36	N/A	2.11	0.00
40	4.00	2.90	3.67	2.03	0.00
40	3.29	3.55	2.86	1.82	0.00
40	3.73	4.18	2.58	1.83	0.00
48	4.78	2.63	2.15	1.67	0.00
48	3.12	2.97	2.14	1.63	0.00
48	4.74	2.48	2.06	1.58	0.00
56	3.40	2.38	N/A	N/A	0.00
56	3.61	2.02	N/A	N/A	0.00
56	3.47	2.60	N/A	N/A	0.00

absence of C9500 at 5 °C and 25 °C. (Hopane Normalized)			
High Conc.			
	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
	162.85	147.15	157.53
	171.87	163.96	154.04
	165.17	164.03	148.16
	143.61	24.70	1.89
	150.68	30.45	8.83
	148.62	11.66	49.04
	139.59	0.00	0.00
	117.09	0.00	0.00
	135.23	0.00	0.00
	N/A	0.00	0.00
	78.39	0.00	0.00
	86.17	0.00	3.70
	54.49	0.00	0.00
	11.66	0.00	0.00
	18.81	N/A	0.22
	0.00	0.00	0.00
	0.00	0.00	0.00
	5.49	0.00	0.00
	0.00	0.00	2.88
	0.00	0.00	0.00
	0.00	0.00	0.00
	2.09	0.00	31.65
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.70	0.00	0.00
	0.00	0.00	0.00
	0.00	N/A	N/A
	2.08	N/A	N/A
	2.83	N/A	N/A
	0.00	N/A	N/A
	0.00	N/A	N/A
	0.00	N/A	N/A

n of n-alkanes (nC17-nC21) in the presence and absence of C9500 at 5 °C and 25 °C. (Hopane Normalize

	Low Conc.				High Conc.
Time	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS	5 °C (ANS+C9500)
0	43.46	60.73	29.09	29.64	78.45
0	N/A	61.43	29.45	30.40	76.47
0	N/A	59.23	31.37	28.77	78.72
2	42.29	55.83	23.96	36.01	59.76
2	40.92	53.07	25.45	33.55	57.11
2	43.27	58.39	24.42	32.98	63.32
4	42.09	55.24	11.31	16.42	34.95
4	42.50	54.50	12.97	17.45	25.61
4	42.42	53.98	8.30	24.21	33.28
8	24.08	37.34	8.22	6.29	5.62
8	30.04	47.41	8.56	6.70	0.00
8	30.42	42.35	7.88	7.78	0.00
12	12.95	16.17	7.15	6.12	0.00
12	11.45	17.67	9.91	5.44	0.00
12	10.52	16.95	8.70	6.07	0.00
16	12.03	16.27	9.97	5.94	0.58
16	10.67	14.38	9.15	5.81	0.31
16	9.49	20.25	8.44	7.05	0.00
24	6.17	8.45	3.45	4.51	0.26
24	11.25	9.43	7.92	3.87	0.00
24	9.90	7.13	7.19	4.60	0.00
32	8.63	6.09	7.07	3.87	0.00
32	3.79	7.37	6.65	3.69	0.00
32	N/A	7.18	N/A	4.79	0.00
40	9.03	6.96	8.93	3.73	0.00
40	6.48	8.35	5.91	3.61	0.00
40	6.00	9.71	5.95	3.58	0.00
48	9.08	6.51	7.28	2.06	0.00
48	5.68	7.62	7.13	2.10	0.00
48	9.97	5.19	6.58	2.12	0.00
56	9.58	8.61	N/A	N/A	0.00
56	10.99	4.58	N/A	N/A	0.00
56	10.45	7.64	N/A	N/A	0.00

nd absence of C9500 at 5 °C and 25 °C. (Hopane Normalized)		
High Conc.		
5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
73.62	68.76	72.83
74.95	75.88	74.11
72.34	79.02	68.27
68.90	13.65	1.58
68.18	15.04	4.30
63.23	5.93	21.56
64.34	0.00	0.28
56.27	0.38	0.24
62.13	0.32	1.43
N/A	0.00	0.62
48.51	0.00	0.55
51.79	0.00	2.66
36.70	0.00	0.47
6.53	0.00	0.49
11.36	N/A	1.46
0.25	0.00	0.69
0.07	0.00	0.07
3.09	0.00	0.35
0.43	0.00	2.47
0.22	0.00	0.00
0.00	0.00	0.00
1.79	0.00	15.92
0.00	0.00	0.00
0.55	0.00	0.00
0.00	0.00	0.00
0.67	0.00	0.00
0.00	0.00	0.00
0.00	N/A	N/A
1.68	N/A	N/A
2.23	N/A	N/A
0.00	N/A	N/A
0.27	N/A	N/A
0.00	N/A	N/A

on of n-alkanes (nC22-nC29) in the presence and absence of C9500 at 5 °C and 25 °C. (Hopane Normaliz

	Low Conc.				High Conc.
Time	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS	5 °C (ANS+C9500)
0	56.50	49.89	27.91	21.79	60.65
0	N/A	50.50	29.33	22.80	60.55
0	N/A	50.07	31.23	22.26	60.95
2	55.04	46.99	27.91	30.80	53.78
2	57.37	49.25	27.36	28.66	48.99
2	57.48	48.97	26.67	29.04	55.32
4	50.52	46.70	7.88	15.66	40.99
4	56.12	47.45	10.33	15.77	35.64
4	53.48	47.47	7.00	21.18	38.89
8	41.63	39.41	9.69	7.18	17.63
8	49.31	48.72	9.10	6.51	3.35
8	49.97	41.72	8.98	8.36	4.04
12	23.89	22.53	8.12	6.05	0.00
12	21.73	17.85	9.49	7.11	0.00
12	21.47	23.89	8.81	6.34	0.00
16	21.68	23.47	11.74	11.55	1.71
16	20.63	20.49	10.92	10.68	1.30
16	31.90	24.82	10.76	9.96	0.00
24	12.65	9.05	5.60	3.78	1.54
24	16.07	8.98	7.62	5.11	0.00
24	15.47	8.42	7.51	5.01	0.00
32	14.51	8.16	7.75	4.61	0.00
32	6.82	8.59	7.33	3.72	0.00
32	N/A	8.02	N/A	5.97	0.00
40	16.96	8.41	9.96	3.98	0.00
40	14.15	9.41	7.90	5.05	0.00
40	13.67	10.38	7.71	5.16	0.00
48	14.18	9.13	5.62	0.00	0.00
48	12.50	13.48	6.12	3.39	0.00
48	14.76	9.45	5.82	7.82	0.00
56	15.99	11.87	N/A	N/A	0.00
56	17.38	10.56	N/A	N/A	0.00
56	16.90	12.35	N/A	N/A	0.00

absence of C9500 at 5 °C and 25 °C. (Hopane Normalized)

High Conc.		
5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
56.30	55.69	58.25
57.97	61.68	58.21
55.87	60.44	54.68
54.42	14.06	2.15
54.53	16.77	4.29
52.69	8.32	27.57
55.61	2.37	0.80
50.66	0.85	0.33
55.12	0.79	2.62
N/A	0.00	1.47
46.43	0.00	1.61
49.10	0.00	4.09
40.94	0.00	1.14
13.37	0.00	1.47
23.50	N/A	1.89
0.27	0.00	2.57
0.52	0.00	0.73
3.86	0.00	0.92
0.28	0.00	4.12
0.25	0.00	0.00
0.00	0.00	0.00
1.88	0.00	15.12
0.00	0.00	0.00
0.69	0.00	0.52
0.00	0.00	0.59
0.73	0.00	0.00
0.00	0.00	0.00
2.55	N/A	N/A
1.66	N/A	N/A
2.20	N/A	N/A
0.00	N/A	N/A
0.27	N/A	N/A
0.00	N/A	N/A

ion of n-alkanes (nC30-nC35) in the presence and absence of C9500 at 5 °C and 25 °C. (Hopane Normali

	Low Conc.				High Conc.
Time	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS	5 °C (ANS+C9500)
0	25.13	20.27	13.30	9.65	12.10
0	N/A	17.31	14.49	9.43	12.90
0	N/A	18.37	14.62	9.29	12.90
2	26.53	16.52	10.30	10.03	12.01
2	27.50	17.84	9.53	10.23	11.65
2	26.68	16.68	8.76	10.13	12.97
4	18.71	17.61	0.00	5.34	10.32
4	24.27	17.85	1.97	5.38	10.70
4	24.43	17.27	1.81	7.78	11.23
8	27.26	20.21	0.00	1.42	7.48
8	27.59	23.85	0.00	1.35	5.40
8	29.56	18.46	0.00	2.35	6.08
12	7.84	14.00	0.00	0.00	3.16
12	7.11	8.85	0.00	0.00	2.55
12	7.58	12.99	0.00	0.00	2.78
16	4.02	19.32	0.00	1.45	1.90
16	3.87	15.02	0.00	1.32	1.21
16	3.77	16.21	0.00	2.96	0.00
24	0.00	8.52	0.00	0.00	0.00
24	3.38	9.18	0.00	0.00	1.58
24	3.37	9.69	0.00	0.00	1.44
32	6.63	10.03	0.00	0.00	1.01
32	0.00	10.59	0.00	0.00	1.53
32	N/A	11.92	N/A	0.88	1.68
40	4.05	11.53	0.00	0.00	1.78
40	3.53	11.09	0.00	0.00	0.92
40	7.42	10.66	0.00	0.00	2.23
48	7.02	6.17	0.00	1.19	1.48
48	0.00	9.42	0.00	1.20	1.13
48	6.88	8.81	0.00	2.31	1.87
56	3.87	8.03	N/A	N/A	1.96
56	3.68	8.26	N/A	N/A	1.73
56	3.87	8.31	N/A	N/A	0.63

absence of C9500 at 5 °C and 25 °C. (Hopane Normalized)		
High Conc.		
5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
13.45	9.54	12.84
14.25	10.77	13.35
13.92	12.01	13.11
12.64	3.62	0.00
12.80	4.71	0.72
12.94	2.88	7.40
12.28	0.00	0.00
11.52	0.00	0.00
12.76	0.00	0.00
N/A	0.00	0.00
10.78	0.00	0.00
11.47	0.00	0.00
9.92	0.00	0.00
5.23	0.00	0.00
9.43	N/A	0.00
0.00	0.00	0.00
0.00	0.00	0.00
1.87	0.00	0.00
0.41	0.00	0.00
0.04	0.00	0.00
0.00	0.00	0.00
0.25	0.00	2.92
0.00	0.00	0.00
0.00	0.00	0.00
0.80	0.00	0.00
0.76	0.00	0.00
0.98	0.00	0.00
2.19	N/A	N/A
0.83	N/A	N/A
1.15	N/A	N/A
0.67	N/A	N/A
0.73	N/A	N/A
1.14	N/A	N/A

idual PAH in the presence and absence of C9500 at 5 °C and 25 °C in high and low concentration experi

	Low Conc.			
Compound	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
nap	100	100	100	100
C1-nap	100	100	100	100
C2-nap	100	100	100	100
C3-nap	100	100	100	100
C4-nap	100	98	93	95
phe	100	100	100	100
C1-phe	100	100	100	100
C2-phe	100	100	100	100
C3-phe	35	47	45	42
C4-phe	13	24	7	0
flu	100	100	100	100
C1-flu	100	100	100	100
C2-flu	100	100	100	100
C3-flu	54	61	66	67
dbt	54	83	69	64
C1-dbt	100	98	100	100
C2-dbt	2	6	0	0
C3-dbt	46	52	55	53
nbt	100	100	100	100
C1-nbt	12	16	20	0
C2-nbt	3	7	2	0
C3-nbt	BDL	BDL	BDL	BDL
C1-pyr	29	43	45	53
C2-pyr	BDL	BDL	BDL	BDL
cry	BDL	BDL	80	68
C1-cry	2	5	3	20
C2-cry	0	4	0	0
C3-cry	BDL	BDL	BDL	BDL
C4-cry	BDL	BDL	BDL	BDL

e of C9500 at 5 °C and 25 °C in high and low concentration experiment. Unit: %

High Conc.			
5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
100	99	100	100
100	100	100	100
100	100	100	100
100	100	100	100
94	84	96	94
100	100	100	100
100	100	100	100
85	66	94	87
19	0	31	11
9	0	10	0
100	100	100	100
100	100	100	100
86	64	96	85
34	7	48	28
100	97	100	100
96	95	98	96
88	69	91	83
33	11	41	22
45	14	42	25
2	0	10	0
0	0	0	0
0	0	0	0
35	12	48	30
5	0	9	0
9	3	24	8
9	0	13	3
6	6	10	0
0	0	0	0
0	1	0	0

BDL: below detection limit

of naphthobenzothiophene homologues in the presence and absence of C9500 at 5 °C and 25 °C. (Hopa					
	Low Conc.				High Conc.
Time	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS	5 °C (ANS+C9500)
0	1.28	1.01	0.74	0.47	2.49
0	N/A	0.96	0.75	0.49	2.52
0	N/A	0.96	0.75	0.47	2.47
2	1.33	0.90	0.87	0.67	2.55
2	1.41	0.95	0.80	0.65	2.38
2	1.33	0.94	0.74	0.66	2.57
4	1.26	0.92	0.69	0.65	2.89
4	1.28	0.92	0.67	0.61	2.75
4	1.26	0.94	0.61	0.64	2.71
8	0.99	1.00	0.59	0.64	2.65
8	1.33	1.16	0.58	0.60	2.48
8	1.40	1.00	0.55	0.59	2.98
12	1.31	0.95	0.52	0.66	1.85
12	1.25	0.78	0.54	0.46	1.83
12	1.10	1.03	0.51	0.59	1.76
16	1.31	1.10	0.55	0.52	2.48
16	1.29	0.99	0.54	0.62	2.36
16	1.25	1.01	0.55	0.63	2.51
24	1.20	0.93	0.52	0.61	2.58
24	1.24	0.82	0.50	0.46	2.45
24	1.20	0.85	0.48	0.47	2.56
32	0.91	0.86	0.49	0.43	2.55
32	0.49	0.79	0.47	0.36	2.58
32	0.00	0.84	N/A	0.43	2.66
40	0.81	0.70	0.67	0.65	2.39
40	0.75	0.83	0.52	0.47	2.34
40	0.74	0.96	0.38	0.48	2.40
48	0.89	0.63	0.53	0.48	2.55
48	0.91	0.68	0.53	0.48	2.38
48	0.87	0.66	0.52	0.43	2.51
56	1.00	0.71	N/A	N/A	2.49
56	0.99	0.78	N/A	N/A	2.51
56	1.44	0.74	N/A	N/A	2.45

and absence of C9500 at 5 °C and 25 °C. (Hopane Normalized)

High Conc.		
5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
2.58	N/A	2.41
2.54	2.31	2.39
2.53	2.45	2.39
2.71	2.43	2.50
2.75	2.21	2.44
2.68	2.24	2.28
2.99	2.48	2.73
2.87	2.46	2.70
2.98	2.62	3.33
N/A	2.63	1.45
2.97	2.61	1.95
3.03	2.69	1.89
3.02	2.18	1.41
3.02	2.31	1.85
3.03	N/A	N/A
2.62	2.15	2.78
2.66	2.13	2.45
2.66	2.13	2.46
2.63	2.29	2.69
2.47	2.26	2.63
2.72	2.20	2.53
2.82	2.27	2.69
2.72	2.38	2.58
2.77	2.35	2.55
2.72	2.22	2.47
2.58	2.35	2.44
2.63	2.26	2.48
2.70	N/A	N/A
2.67	N/A	N/A
2.80	N/A	N/A
2.57	N/A	N/A
2.81	N/A	N/A
2.75	N/A	N/A

Homologues + Chrysene Homologues in the presence and absence of C9500 at 5 °C and 25 °C. (Hopane

	Low Conc.			
Time	5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
0	2.12	2.08	1.45	1.61
0	N/A	1.87	1.43	1.51
0	N/A	1.98	1.55	1.43
2	1.92	1.63	1.53	1.41
2	1.97	1.67	1.58	1.38
2	2.09	1.80	1.41	1.41
4	1.90	1.71	1.39	1.42
4	1.90	1.74	1.34	1.45
4	1.98	1.74	1.25	1.43
8	1.43	1.78	1.01	1.32
8	1.43	1.82	0.96	1.23
8	1.55	1.82	0.93	1.31
12	2.02	1.71	0.99	1.21
12	1.96	1.69	1.00	1.14
12	2.04	1.68	0.94	1.15
16	1.94	1.84	0.97	1.26
16	1.91	1.75	0.92	1.30
16	1.90	1.83	0.96	1.35
24	2.03	1.71	1.08	1.19
24	2.00	1.67	1.05	1.14
24	2.13	1.71	0.93	1.18
32	1.94	1.65	1.19	1.16
32	1.16	1.64	1.15	1.08
32	N/A	1.68	N/A	1.15
40	1.57	1.65	1.13	1.50
40	1.58	1.81	0.97	1.01
40	1.41	1.96	0.99	1.09
48	2.06	1.53	1.28	1.20
48	1.99	1.64	1.37	1.18
48	1.92	1.67	1.25	1.14
56	1.64	1.71	N/A	N/A
56	1.69	1.72	N/A	N/A
56	1.93	1.73	N/A	N/A

ues in the presence and absence of C9500 at 5 °C and 25 °C. (Hopane Normalized)

High Conc.			
5 °C (ANS+C9500)	5 °C ANS	25 °C (ANS+C9500)	25 °C ANS
3.25	3.44	N/A	3.42
3.41	3.47	3.33	3.43
3.40	3.41	3.46	3.30
3.25	3.44	3.21	3.27
3.02	3.42	3.20	3.19
3.26	3.28	3.15	2.88
3.42	3.54	3.08	3.14
3.33	3.41	2.96	3.20
3.40	3.55	3.17	3.70
3.00	N/A	2.97	1.63
2.97	3.43	3.00	2.24
3.39	3.49	3.03	2.13
2.13	3.50	2.84	1.84
2.12	3.41	3.11	2.49
1.98	3.53	N/A	N/A
3.19	3.31	2.94	3.13
2.99	3.24	2.87	3.14
3.18	3.31	2.80	3.25
3.19	3.33	2.79	3.25
2.97	2.93	2.80	3.07
3.18	3.20	2.74	3.07
3.08	3.56	2.72	3.32
3.11	3.26	2.98	3.02
3.15	3.30	2.87	3.16
3.15	3.55	2.89	3.42
3.07	3.43	3.24	3.24
3.23	3.47	2.97	3.23
3.21	3.46	N/A	N/A
3.02	3.36	N/A	N/A
3.30	3.43	N/A	N/A
3.16	3.27	N/A	N/A
3.16	3.48	N/A	N/A
3.13	3.48	N/A	N/A

Biodegradation of hopane-normalized total alkanes at both temperatures in killed control samples.					
	Low Conc.				
Time	5 °C (ANS+C9500) Killed	25 °C (ANS+C9500) Killed	Time	5 °C ANS Killed	25 °C ANS Killed
0	201.19	106.28	0	212.64	103.23
0	N/A	111.69	0	215.69	110.47
0	N/A	115.79	0	201.05	106.13
2	188.85	109.22	48	N/A	65.71
2	193.84	107.48	48	N/A	100.68
2	N/A	115.91	48	N/A	79.39
4	207.53	94.27	56	176.29	N/A
4	207.27	103.39	56	201.79	N/A
4	199.48	94.60	56	185.69	N/A
8	195.09	99.40			
8	N/A	98.50			
8	203.86	105.19			
12	198.66	96.99			
12	195.27	101.40			
12	N/A	92.99			
16	N/A	N/A			
16	214.10	109.66			
16	193.17	94.15			
24	203.19	90.37			
24	191.77	96.50			
24	199.14	83.84			
32	198.75	81.10			
32	205.41	92.71			
32	192.43	87.02			
40	204.58	85.19			
40	184.95	84.20			
40	191.63	80.48			
48	198.82	100.12			
48	193.92	N/A			
48	193.39	90.43			
56	200.17	N/A			
56	197.08	N/A			
56	199.21	N/A			

tal alkanes at both temperatures in killed control samples.

High Conc.				
5 °C (ANS+C9500) Killed	25 °C (ANS+C9500) killed	Time	5 °C ANS Killed	25 °C ANS Killed
324.00	298.51	0	323.27	318.85
317.28	330.78	0	337.09	316.96
332.29	333.70	0	324.56	300.42
295.42	286.23	40	N/A	284.55
326.16	275.50	40	N/A	236.64
312.15	270.97	40	N/A	320.20
266.79	252.38	56	370.83	N/A
292.12	258.68	56	368.25	N/A
295.18	244.03	56	367.53	N/A
308.75	276.45			
306.35	272.15			
304.03	270.84			
336.62	295.39			
327.41	N/A			
326.12	N/A			
310.24	310.24			
322.89	322.89			
327.34	327.34			
325.16	281.09			
309.90	264.57			
316.43	276.04			
347.30	300.82			
336.36	268.96			
344.82	272.35			
352.86	284.55			
336.53	236.64			
358.17	320.20			
353.87	N/A			
361.78	N/A			
364.63	N/A			
327.97	N/A			
353.50	N/A			
361.63	N/A			

odegradation of hopane-normalized total PAHs at both temperatures in killed control samples.

	Low Conc.				
Time	5 °C (ANS+C9500) Killed	25 °C (ANS+C9500) killed	Time	5 °C ANS Killed	25 °C ANS Killed
0	51.17	42.79	0	52.01	48.24
0	N/A	44.48	0	51.70	46.65
0	N/A	45.87	0	47.45	45.24
2	43.83	43.56	48	N/A	40.86
2	44.56	41.10	48	N/A	43.49
2	N/A	45.32	48	N/A	45.69
4	51.17	42.05	56	55.51	N/A
4	52.20	42.01	56	59.74	N/A
4	48.66	39.98	56	60.88	N/A
8	46.22	42.48			
8	N/A	41.54			
8	49.62	40.97			
12	48.41	41.65			
12	49.20	43.16			
12	N/A	37.95			
16	N/A	N/A			
16	51.37	46.72			
16	46.91	41.08			
24	55.21	40.21			
24	51.47	41.11			
24	52.73	41.41			
32	49.89	41.80			
32	53.75	45.84			
32	51.52	45.19			
40	52.46	43.77			
40	47.06	43.32			
40	48.75	41.89			
48	53.41	44.79			
48	53.12	N/A			
48	54.08	44.17			
56	50.61	N/A			
56	53.20	N/A			
56	51.10	N/A			

total PAHs at both temperatures in killed control samples.

High Conc.				
5 °C (ANS+C9500) Killed	25 °C (ANS+C9500) Killed	Time	5 °C ANS Killed	25 °C ANS Killed
95.81	N/A	0	98.86	101.86
94.35	107.21	0	103.69	99.41
96.46	106.42	0	101.52	94.89
86.13	97.04	40	N/A	101.88
97.50	92.57	40	N/A	88.57
94.17	94.08	40	N/A	100.23
80.91	89.58	56	106.09	N/A
88.91	92.81	56	103.58	N/A
87.59	86.34	56	104.57	N/A
92.66	98.93			
92.13	96.63			
89.98	95.58			
93.94	98.78			
89.18	N/A			
92.55	N/A			
86.34	93.03			
89.46	92.14			
91.11	90.89			
89.32	98.05			
86.01	93.62			
86.15	95.81			
98.48	100.70			
95.08	98.94			
95.26	99.18			
95.49	97.16			
92.12	94.93			
96.37	95.62			
146.91	N/A			
83.75	N/A			
80.01	N/A			
92.54	N/A			
98.04	N/A			
96.40	N/A			

Technical Manuscript Review Form

Select an Option

Title Biodegradability of Different Initial Concentrations of Alaska North Slope Crude Oil Dispersed with Corexit C9500	**Author(s)** Mobing Zhuang, Gulizhaer Abulikemu, Pablo Campo, William Platten III, Makram T. Suidan, Albert Venosa, Robyn N Conmy
Date Review Requested 05/09/2016 **Date Review Required** 05/31/2016	**Project Officer/Organization/Address** Robyn Conmy EPA ORD NRMRL -Land Remediation Pollution Control Division 26 W MLK, Cincinnati OH 45268
Type of Publication/Audience manuscript	**Reviewer/Organization/Address** Michael Elovitz EPA ORD NRMRL - Water Supply and Water Resources Division 26 W MLK, Cincinnati OH 45268
Review Coordinator (e.g., PO, TIM, Supervisor) PO - Robyn Conmy TIM - Kim McClellan Supervisor - Joseph Schubauer-Berigan	

You are asked to review and comment on the attached manuscript. Feel free to make notations on the manuscript as well as in the comments section below, particularly regarding your recommendations for revisions. If you are unable to review the manuscript by the required date, please return it now. Your suggestions for alternate or additional reviewers will be welcomed.

SUMMARY RATING		
Please rate the manuscript as follows:	**Satisfactory**	**Unsatisfactory**
Content & Scope	☐	☐
Organization & Presentation	☐	☐
Quality of data & validity of analytical techniques	☐	☐
Soundness of Conclusions	☐	☐
Editorial Quality	☐	☐
Other (specify)	☐	☐
	☐	☐
	☐	☐

RECOMMENDATIONS

G (1) ☐ **Acceptable as is**

G (2) ☐ **Acceptable after minor revisions**

G (3) ☐ **Acceptable after major revisions**

G (4) ☐ **Not acceptable**

If you have checked either 3 or 4, please specifically state reason(s) in the comments space below.

Reviewer's Signature SIGN **Date**

Comments:

Tech. Rev. Form EPA363

Audit Trail for

Technical Manuscript Review Form

PDF Name: TMRF_363.pdf
Form Number: EPA363
Document Identifier: EPA363-12250124123-RC

To: Voit, Jim[Voit.Jim@epa.gov]
From: Conmy, Robyn
Sent: Fri 2/12/2016 12:43:34 PM
Subject: QA review of a new interagency agreement project
BSEE_EPA_DFO_NJIT hypersaline DE technical proposal submitted.docx

Hi Jim,

ORD is in the process of establishing a new interagency agreement (IA) with DOI BSEE for oil dispersion effectiveness testing. This work will be partly conducted at AWBERC (bench scale baffled flask work) and the wave tank in Dartmouth Nova Scotia (similar to previous experiments there). For the work at AWBERC, we will be using the existing QAPP for the oil dispersion effectiveness, but running experiments over a range of salinities to test the effect. I assume this will require an amendment to the QAPP which we will submit this Spring.

Attached are the proposal for the IA. Cynthia Johnson and I have begun a decision memo in IGMS, which of course requires a QA review.

Not sure what your queue looks like these days. How long can we expect such a review to take?

Thanks,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

To: Scott Pegau[wspegau@pwssc.org]
From: Conmy, Robyn
Sent: Mon 1/4/2016 12:13:20 PM
Subject: RE: fluorometer paper
conmy et al 2014 ES&T_published.pdf

Here you go Scott. Happy New Year!

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Scott Pegau [mailto:wspegau@pwssc.org]
Sent: Thursday, December 31, 2015 12:21 PM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Subject: fluorometer paper

Hi Robyn,

I don't have electronic access to ES&T. Do you have a pdf of

Conmy, R. N., P. G. Coble, J. Farr, A. M. Woods, K. Lee, W. S. Pegau, I. D. Walsh, C. R. Koch, M. I. Abercrombie, M. S. Miles, M. R. Lewis, S. A Ryan, B. J. Robinson, T. L King, C. R. Kelble, and J. Lacoste. 2014. Submersible Optical Sensors Exposed to Chemically Dispersed Crude Oil: Tank

Simulations for Improved Oil Spill Monitoring. ***Environmental Science and Technology.*** **48. 1803-1810.**

that you can share with me?

Thanks

Scott

W. Scott Pegau

Research Program Manager

Oil Spill Recovery Institute

Box 705

Cordova, AK 99574

907-424-5800 x222

www.pws-osri.org

To: Holder, Edith[holder.edith@epa.gov]
Cc: Herrmann, Ronald[Herrmann.Ronald@epa.gov]
From: Conmy, Robyn
Sent: Wed 7/13/2016 4:54:35 PM
Subject: Re: fyi

I can request but the email address auto fill doesn't work with the phone. What is larry's address?

Sent from my iPhone

On Jul 13, 2016, at 11:20 AM, Holder, Edith <holder.edith@epa.gov> wrote:

Robyn,

Can you authorize a replacement N2 dewar? Please request one from Larry Wetzel for room 427.

Ron,

I know that Robyn is in DC today. As co-PI can you handle this?

Thanks,

Edie

From: Adkins, Renata
Sent: Wednesday, July 13, 2016 9:25 AM
To: Holder, Edith <holder.edith@epa.gov>; Sundaravadivelu, Devi <sundaravadivelu.devi@epa.gov>
Subject: RE: fyi

Hello,

Unfortunately, the N2 dewar in 427 is empty now. I cannot continue blow downs until I receive a replacement. Do we have a status on an order?

Renata

From: Holder, Edith
Sent: Tuesday, July 12, 2016 1:36 PM
To: Adkins, Renata <Adkins.Renata@epa.gov>; Sundaravadivelu, Devi <sundaravadivelu.devi@epa.gov>
Subject: FW: fyi

Renata,

This is the list of all the samples that will be generated by July 14.

The ones from this Monday, July 11 are ANS – C9500 60 ppt and ANS-Accell 60 and 75 ppt. On Thursday ANS C9500 and Accell @ 50 ppt will be tested.

Edie

From: Holder, Edith
Sent: Tuesday, July 12, 2016 12:56 PM
To: Grosser, Robert <Grosser.Robert@epa.gov>
Subject: fyi

Bob,

Here is a list of samples that we have generated for UV/Vis Analysis. The colored ones are the ones you measured last week.

There are standards for each oil/dispersant combination.

Enjoy!

samples ready for analyses after July 14

ANS	C9500A	35 ppt	5C	25C
	C9500A	40 ppt	5C	25C
	C9500A	50 ppt	5C	25C
	C9500A	60 ppt	5C	25C
	C9500A	75 ppt	5C	25C
	C9500A	100 ppt	5C	25C
	Accel	35 ppt	5C	25C
	Accel	40 ppt	5C	25C
	Accel	50 ppt	5C	25C
	Accel	60 ppt	5C	25C
	Accel	75 ppt	5C	25C
	Accel	100 ppt	5C	25C
	Finasol	35 ppt	5C	25C
	Finasol	40 ppt	5C	
	Dispersit	35 ppt	5C	25C
	none	35 ppt	5C	25C
IFO120	C9500A	35 ppt	5C	25C
	Accel	35 ppt	5C	25C
	Finasol	35 ppt	5C	25C
	Dispersit	35 ppt	5C	25C
	none	35 ppt	5C	25C
Dorado	C9500A	35 ppt	5C	25C
	Accel	35 ppt	5C	25C
	Finasol	35 ppt	5C	25C
	Dispersit	35 ppt	5C	25C
	none	35 ppt	5C	25C

Edith L. Holder

Pegasus Technical Services, Inc.

On-Site Contractor to the U.S. EPA

ORD/NRMRL/LRPCD

26 W. Martin Luther King Dr.

Cincinnati, OH 45268

Phone: 513-569-7178

Email: holder.edith@epa.gov

To: Dyson, Brian[Dyson.Brian@epa.gov]; McClellan, Kim[Mcclellan.Kim@epa.gov]
Cc: Herrmann, Ronald[Herrmann.Ronald@epa.gov]
From: Conmy, Robyn
Sent: Fri 9/18/2015 12:35:19 PM
Subject: RE: STICS Entries

Hi Kim et al.,

I am back from RTP and can help with these submissions. Thank you Brian and Ron for helping out with these submissions thus far. Kim, please just email me with questions regarding these submissions. As of right now do you still not have internal reviews for these?

Thanks,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Dyson, Brian
Sent: Thursday, September 17, 2015 8:11 PM
To: McClellan, Kim
Cc: Herrmann, Ronald; Conmy, Robyn

Subject: RE: STICS Entries

I can't help you with that. I entered those as a favor and was not given that information.

I think Ron Herrmann or Robyn Conmy might know.

From: McClellan, Kim
Sent: Tuesday, September 15, 2015 1:01 PM
To: Dyson, Brian
Subject: STICS Entries

Hi Brian,

All of your STICS entries are not complete. I need this additional information before these abstracts can be submitted to clearance.

You need one internal technical review (reviewer can be from inside or outside of the clearing author's Division) using EPA Form 363 + Reviewer comments for each of these abstracts.

You also need to include the Meeting Name, the Start and End Dates, the Country, State, and City of this conference.

The abstracts are listed below:

TIM Approval	Brian Dyson	Devi Sundaravadivelu	ORD-013921	Evaluation of Sorbent and Solidifier Properties and their Impact on Oil Removal Efficiency	Abstract	9/11/2015 4:43 PM
TIM Approval	Brian Dyson	Mobing Zhuang	ORD-013917	Biodegradability of Dispersed Heavy Fuel Oil at 5 and 25 C	Abstract	9/11/2015 4:28 PM
TIM Approval	Brian Dyson	Yu Zhang	ORD-013915	Biodegradation of Finasol OSR 52 and Dispersed Alaska North Slope Crude Oil at 5 C and 25 C	Abstract	9/11/2015 3:34 PM
TIM Approval	Brian Dyson	Ruta Deshpande	ORD-013912	Biodegradability Of Diluted Bitumen Oil By Kalamazoo River Cultures In Freshwater	Abstract	9/11/2015 2:57 PM

Thanks,

Kim

To: Devi Sundaravadivelu[devis.255@gmail.com]
Cc: Raghuraman Venkatapathy[raghuraman.venkatapathy@ptsied.com]; SORIALGA@UCMAIL.UC.EDU[SORIALGA@ucmail.uc.edu]; p.campo-moreno@cranfield.ac.uk[p.campo-moreno@cranfield.ac.uk]; Holder, Edith[holder.edith@epa.gov]; Deshpande, Ruta (deshpars)[deshpars@mail.uc.edu]; zhang4y5@mail.uc.edu[zhang4y5@mail.uc.edu]; Zhuang, Mobing (zhuangmg)[zhuangmg@mail.uc.edu]
From: Conmy, Robyn
Sent: Tue 1/19/2016 12:43:46 PM
Subject: RE: GoMRI presentations

Thank you for sending Devi – and thanks to all for putting together these posters! I will enter them into the STICS clearance system today.

Cheers,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

From: Devi Sundaravadivelu [mailto:devis.255@gmail.com]
Sent: Friday, January 15, 2016 4:22 PM
To: Conmy, Robyn <Conmy.Robyn@epa.gov>
Cc: Raghuraman Venkatapathy <raghuraman.venkatapathy@ptsied.com>; SORIALGA@UCMAIL.UC.EDU; p.campo-moreno@cranfield.ac.uk; Holder, Edith <holder.edith@epa.gov>; Deshpande, Ruta (deshpars) <deshpars@mail.uc.edu>; zhang4y5@mail.uc.edu; Zhuang, Mobing (zhuangmg) <zhuangmg@mail.uc.edu>
Subject: Re: GoMRI presentations

Robyn,

We were able to finish the posters today.

I've attached 4 posters for EPA clearance review. They are:

1. Biodegradation of Finasol OSR 52 and Dispersed Alaska North Slope Crude Oil at 5 C and 25 C *(WA 0-05, Task 1.1)*

2. Biodegradability of Dispersed Heavy Fuel Oil at 5 and 25 C *(WA 0-05, Task 1.1)*

3. Biodegradability Of Diluted Bitumen Oil By Kalamazoo River Cultures In Freshwater *(WA 0-05, Task 1.2)*

4. Evaluation of Sorbent and Solidifier Properties and their Impact on Oil Removal Efficiency *(WA 0-05, Task 2.3)*

The abstracts were originally cleared on 9/16/2015 (ORD-013915, ORD-013917, ORD-013912, and ORD-013921 respectively). Please let me know if there are any questions.

Thanks,

Devi

On Fri, Jan 15, 2016 at 10:26 AM, Conmy, Robyn <Conmy.Robyn@epa.gov> wrote:

> Ruta, Devi, Yu, and Edie,
>
> Hopefully you are all close to having your presentations ready for EPA clearance review. I will be entering your presentations into the review system on Tuesday. So, although today was the deadline to me, you don't need to send to me until Tuesday morning if you need a few more days to finish. That being said, I do not know if Edie still would like to see them today, so please check with her on that.

In any case, I will look for your presentations by Tuesday.

Cheers,

Robyn

<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>/<>

Robyn N. Conmy, Ph.D.

Research Ecologist

USEPA/NRMRL/LRPCD

26 West MLK Drive

Cincinnati, Ohio 45268

513-569-7090 (office)

513-431-1970 (EPA mobile)

727-692-5333 (Personal mobile)

conmy.robyn@epa.gov

OIL POLLUTION RESEARCH AND TECHNOLOGY PLAN

Fiscal Years 2015-2021

INTERAGENCY COORDINATING COMMITEE ON OIL POLLUTION RESEARCH (ICCOPR)

September 2015

DISCLAIMER

This Oil Pollution Research and Technology Plan (OPRTP) presents the collective opinion of the 15 departments and agencies that constitute the members of Interagency Coordinating Committee on Oil Pollution Research (ICCOPR), regarding the status and current focus of the federal oil pollution research, development, and demonstration program (established pursuant to section 7001(c) of the Oil Pollution Act of 1990 (33 U.S.C. 2761(c))). The statements, positions, and research priorities contained in this OPRTP may not necessarily reflect the views or policies of an individual department or agency, including any component of a department or agency that is a member of ICCOPR. This OPRTP does not establish any regulatory requirement or interpretation, nor implies the need to establish a new regulatory requirement or modify an existing regulatory requirement.

TABLE OF CONTENTS

ED_001324_00001035-00004

ED_001324_00001035-00009

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

A-CORE	Arctic Center for Oil-Spill Research & Education
AAR	After Action Review
AC	Area Committee
ACP	Area Committee Plan
ADEC	Alaska Department of Environmental Conservation
ADEQ	Arkansas Division of Environmental Quality
AESC	Arctic Executive Steering Committee
AIP	Australian Institute of Petroleum
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Maritime Safety Authority
API	American Petroleum Institute
APICOM	Association of Petroleum Industry Co-op Managers
ARTES	Alternative Response Technologies Evaluation System
BAST	Best Available and Safest Technology
bbl (s)	Barrel (equals 42 U.S. Gallons)
BIO COOGER	DFO Canada's Bedford Institute of Oceanography Center for Offshore Oil, Gas and Energy Research
BOEM	Bureau of Ocean Energy Management
BOEMRE	[former] Bureau of Ocean Energy Management, Regulation and Enforcement
BP	British Petroleum
Bpd	Barrels per day
BSEE	Bureau of Safety & Environmental Enforcement
CAOSPR	California Office of Oil Spill Prevention and Response
CASP	Center for Arctic Study & Policy
CEC	CEDRE Experimentation Column
CEDRE	Centre of Documentation, Research and Experimentation on Accidental Water Pollution
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Resource, Compensation, and Liability Act
CFR	Code of Federal Regulations
CGHQ	Coast Guard Headquarters
CIRCAC	Cook Inlet Regional Citizen's Advisory Committee
CMR	Center of Excellence for Maritime Research
COP	Common Operating Picture
CPF	Coastal Protection Fund
CRADA	Cooperative Research and Development Agreement
CRRC	Coastal Response Research Center
CRREL	Cold Regions Research and Engineering Laboratory

CSE	Center for Spills in the Environment
CSIRO	Commonwealth Scientific and Industrial Research Organization
CWA	Clean Water Act
DDO	Dispersants and dispersed oil
DECC	Department of Energy and Climate Change
DFO	Department of Fisheries and Oceans Canada
DHHS	Department of Health and Human Services
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOR	Dispersant to Oil Ratio
DOT	Department of Transportation
DWH	*Deepwater Horizon*
E&P	Exploration & Production
EC	Environment Canada; European Union
EDDM	Environmental Disasters Data Management
EDRC	Effective Daily Recovery Capacity
EDRP	Emergency Disaster Recovery Program
EEZ	Exclusive Economic Zone
EIA	U.S. Energy Information Administration
EMERCOM	Russian Ministry of Civil Defense, Emergencies and Disaster Response
EMSA	European Maritime Safety Agency
EOI	Expression of Interest
EOP	Executive Office of the President
EPA	Environmental Protection Agency
EPAct	Energy Policy Act of 2005
EPPR	Emergency Prevention, Preparedness and Response Working Group
ERA	Environmental Risk Assessments
ERDC	U.S. Army Engineer Research and Development Center
ERRC	European Response Coordination Center
ERT	Environmental Response Team
ERW	Electric resistance welded pipe
ESA	Endangered Species Act
ESB	Environmental Specimen Bank
ESI	Environmental Sensitivity Index
ESP	Environmental Studies Program
EU	European Union
FACA	Federal Advisory Committee Act
FMSAS	Florida Marine Spill Analysis System

FEMA	Federal Emergency Management Agency
FIO	Florida Institute of Oceanography
FOSC	Federal-On Scene Coordinator
FOSTERRS	Federal Oil Spill Team for Emergency Response Remote Sensing
FWPCA	Federal Water Pollution Control Administration
GIRG	Global Industry Response Group
GIS	Geographic Information Systems
GMFMC	Gulf of Mexico Fishery Management Council
GOMA	Gulf of Mexico Alliance
GoMRI	Gulf of Mexico Research Initiative
GOMURC	Gulf of Mexico University Research Collaborative
GRP	[National Academy of Science] Gulf Research Program
GSMFC	Gulf States Marine Fisheries Commission
HAZMAT	Hazardous Material
HML	Hollings Marine Laboratory
HMTA	Hazardous Materials Transportation Act
ICCOPR	Interagency Coordinating Committee on Oil Pollution Research
ICS	Incident Command System
ILI	In-Line Inspection
IMO	International Maritime Organization
IOM	Institute of Medicine
IOOS	Integrated Ocean Observing System
IOSC	International Oil Spill Conference
IPIECA	International Petroleum Industry Environmental Conservation Association
ISB	In-situ Burn
ISCO	International Spill Control Organization
ISPR	Incident Specific Preparedness Reviews
ITAC	Industry Technical Advisory Committee
ITOPF	International Tanker Owners Pollution Federation Limited
JITF	Joint Industry Oil Spill Preparedness and Response Task Force
JIP	Joint Industry Programme; Joint Industry Program
LEGEEPA	General Law of Ecological Equilibrium and Environmental Protection
LiDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
MARAD	Maritime Administration
MARPOL	Marine Pollution (International convention for the Prevention of Pollution from Ships)
MCA	Maritime and Coastguard Agency
MER	Marine Environmental Response
META	Maritime Environmental and Technical Assistance
MMC	U.S. Marine Mammal Commission

MMPA	Marine Mammal Protection Act
MMS	[former] Minerals Management Service
MOC-A	Marine Operations Center, Atlantic
MOC-P	Marine Operations Center, Pacific
MOC-PI	Marine Operations Center, Pacific Islands
MODU	Mobile Offshore Drilling Units
MPCSA	State Marine Pollution Control, Salvage and Rescue Administration
MPD	Managed pressure drilling
MRCC	Marine Rescue Coordination Centres
MSA	China Maritime Safety Administration
MSL	USCG Marine Safety Laboratory
MTBE	Methyl Tertiary Butyl Ether
NAS	National Academy of Sciences
NASA	National Aeronautics & Space Administration
NAVSEA	Naval Sea Systems Command
NAWCA	North American Wetlands Conservation Act
NDRF	National Defense Reserve Fleet
NEBA	Net Environmental Benefit Analysis
NEPA	National Environmental Policy Act
NCP	National Contingency Plan
NETL	DOE's National Energy Technology Laboratory
NFWF	National Fish and Wildlife Federation
NGO	Non-governmental Organization
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPC	National Petroleum Council
NPFC	U.S. Coast Guard's National Pollution Funds Center
NRC	National Response Center; National Research Council
NRDA	Natural Resource Damage Assessment
NRDAR	Natural Resource Damage Assessment and Restoration
NRF	National Response Framework
NRL	U.S. Naval Research Laboratory
NRMR	U.S. EPA National Risk Management Research Laboratory
NRP	National Response Plan
NRT	National Response Team
S&T	National Response Team Science & Technology Committee
NSAR	National Strategy for the Arctic Region
NSCS	National Spill Control School

NSF	National Science Foundation
NSTC	National Science and Technology Council
NTIS	National Technical Information Service
NTNU	Norwegian University of Science and Technology
NTSB	National Transportation Safety Board
NURail	National University Rail (NURail) Center
OCRE	Ocean Coastal Research Engineering
OCS	Outer Continental Shelf
ODRP	Oil Disaster Recovery Program
OESI	Ocean Energy Safety Institute
OGP	Oil and Gas Producers
OMAO	NOAA's Office of Marine and Aviation Operations
OPA 90	Oil Pollution Act of 1990
OPRTP	Oil Pollution Research & Technology Plan
OR&R	NOAA Office of Response & Restoration
OSC	On Scene Coordinator
OSHA	Occupational Safety & Health Administration
OSPR	Oil Spill Preparedness and Response
OSRADP	Oil Spill Research and Development Program
OSRI	Oil Spill Recovery Institute
OSRO	Oil Spill Removal Organization
OSP	Oil Sands Products
OSLTF	Oil Spill Liability Trust Fund
OST	[Executive Office of the President] Office of Science & Technology
OSV	Ocean Survey Vessel
OSWG	Oil Spill Working Group
PAJ	Petroleum Association of Japan
PCT	Pew Charitable Trusts
PEMEX	Petróleos Mexicanos
PERF	Petroleum Environmental Research Forum
PHMSA	Pipeline & Hazardous Materials Safety Administration
PI	Principal investigators
P.L.	Public Law
PNNL	Pacific Northwest National Laboratory
PRCI	Pipeline Research Council International
PRI	Paleontological Research Institution
PROMAM	Navy's Marine Environment Protection Division
PSBCOSTF	Pacific States/British Columbia Oil Spill Task Force
PTSA	Port and Tanker Safety Act of 1978
PWS	Prince William Sound

PWSA	Ports and Waterways Safety Act of 1972
PWSRCAC	Prince William Sound Regional Citizen's Advisory Committee
RAPID	Rapid Response Research
RAR	Resources at Risk
RDC	Coast Guard Research & Development Center
RDT&E	Research, Development, Test, and Evaluation
R&D	Research & Development
R&T	Research & Technology
RESTORE	Resources and Ecosystem Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act
RFP	Request for Proposal
ROV	Remotely Operated Vehicle
ROW	Right of Way
RP	Responsible Party
RRT	Regional Response Team
RSPA	[former] Research and Special Projects Administration
S&T	Science and Technology
SCAA	Spill Control Association of America
SCAT	Shoreline Cleanup Assessment Technique
SETAC	Society of Environmental Toxicology and Chemistry
SIO	Scripps Institution of Oceanography
SIT	Stevens Institute of Technology
SMART	Special Monitoring of Applied Response Technologies
SME	Subject Matter Expert
SONS	Spill of National Significance
SPCC	Spill Prevention, Control & Countermeasures
SRA	Standing Research Areas
SRM	Standard Reference Materials
SSC	NOAA Scientific Support Coordinator
SUPSALV	NAVSEA Supervisor of Salvage and Diving
SwRI	Southwest Research Institute
TCEQ	Texas Commission on Environmental Quality
TDC	Technology Development Center
TPWD	Texas Parks and Wildlife Department
TRB	Transportation Research Board
TXGLO	Texas General Land Office
UAA	University of Alaska Anchorage
UAF	University of Alaska Fairbanks
UDAC	Ultra-Deepwater Advisory Committee
UDW	Ultra-Deepwater

UIUC	University of Illinois Urbana
UNEP	United Nations Environment Programme
UNH	University of New Hampshire
USACE	United States Army Corps of Engineers
USARC	United States Arctic Research Commission
USCG	United States Coast Guard
USGS	United States Geological Survey
USFA	United States Fire Administration
USFWS	United States Fish and Wildlife Service
USN	United States Navy
UTC	University Transportation Center
VOC	Volatile Organic Compound
VTS	Vessel Traffic Service
VTSS	Vessel Traffic Service / Separation
WADOE	Washington Department of Ecology
WHOI	Woods Hole Oceanographic Institution

THIS PAGE INTENTIONALLY LEFT BLANK.

DEFINITIONS

ICCOPR uses the following definitions solely for purposes of this Oil Pollution Research and Technology Plan (OPRTP). These definitions do not reflect all existing/relevant statutory and/or regulatory definitions and do not supersede any statutory or regulatory requirements.

Allision is the running of one vessel against another vessel or structure that is stationary. An allision is different from a collision in that a collision is the running of two moving vessels against each other.

Applied Research is any systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met, in this case related to advancing knowledge about oil spill prevention, preparedness, response, mitigation, and restoration/recovery.

Basic Research is any systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

Baseline Study refers to studies conducted to gather a set of critical observations or data that provide a basis for comparing conditions before and after an action or event. Baseline studies document the ecological and socioeconomic conditions of an area before an oil system activity or potential spill occurs. These studies provide a basis for assessing changes or damages that occur as a result of the activities or a spill.

Collision means the running of two vessels against each other (both under power). A collision is different from an allision where only a single vessel is underway and strikes a stationary vessel or structure.

Damages means injury to natural resources, to real or personal property, loss of subsistence use of natural resources, loss of governmental revenues, loss of profits or earning capacity, and increased cost of additional public services. Damages also include the cost of assessing these injuries. Removal costs and damages covered by OPA 90 are defined in 33 U.S.C § 2702(b)(2).

Demonstration refers to activities that are part of research or development (i.e., that are intended to prove or to test whether a technology or method does, in fact, work). Demonstrations intended primarily to make information available about new technologies or methods should not be included in this definition (NSF, 2009).

Development is any systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

Discharge means any emission (other than natural seepage), intentional or unintentional, and includes, but is not limited to spilling, leaking, pumping, pouring, emitting, or dumping of oil that is not permitted.

Dispersants means those chemical agents that emulsify, disperse, or solubilize oil into the water column or promote the surface spreading of oil slicks to facilitate dispersal of the oil into the water column

Facility means any structure, group of structures, equipment, or device (other than a vessel) that is used for one or more of the following purposes: exploring for, drilling for, producing, storing, handling, transferring, processing, or transporting oil. This term includes any motor vehicle, rolling stock, or pipeline used for one or more of these purposes. The OPA 90 definition of a facility is codified at 33 U.S.C § 2702(b)(2).

National Contingency Plan (NCP) refers to the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), the federal government's blueprint for responding to both oil spills and hazardous substance releases. The NCP is the result of efforts to develop a national response capability and promote coordination among the hierarchy of responders and contingency plans.

Natural Resource Damage Assessment (or assessment) means the process of collecting and analyzing information to evaluate the nature and extent of injuries resulting from an incident, and determine the restoration actions needed to bring injured natural resources and services back to baseline and make the environment and public whole for interim losses.

Natural Resources, for purposes of injury assessment and restoration, refers to land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States (including the resources of the exclusive economic zone), any State or local government or Indian tribe, or any foreign government. Natural resources, for other purposes, may include minerals such as oil and gas.

Oil refers to oil of any kind or in any form, including, but not limited to, petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil. It may also refer to: fats, oils, or greases of animal, fish, or marine mammal origin; vegetable oils, including oils from seeds, nuts, fruits, or kernels; and, other oils and greases, including synthetic and mineral oils. The CWA definition of oil is codified at 33 U.S.C. § 1251 *et seq.*; the OPA definition of oil is codified at 33 U.S.C. § 2701 *et seq.*

The ***Oil Pollution Act of 1990*** (OPA 90), codified at 33 U.S.C § 2701 *et seq.*, is a law that amended the Clean Water Act (CWA) and addressed the wide range of problems associated with preventing, responding to, and paying for oil pollution incidents in navigable waters of the United States. Title VII of OPA 90 established ICCOPR.

An ***Oil Spill*** is a non-permitted occurrence or series of occurrences having the same origin, involving one or more vessels, facilities, or any combination thereof, resulting in the discharge or substantial threat of discharge of oil into or upon navigable waters of the United States, adjoining shorelines, or the exclusive economic zone (e.g., oil spill in coastal waters from a tanker). This term also includes discharges of oil on land with the potential to reach any waters of the United States.

Oil Spill Response Organizations (OSROs) are companies that specialize in cleaning up oil spills. They often serve as contractors or subcontractors for spill response efforts.

An ***On-Scene Coordinator*** (OSC) is the federal official pre-designated by EPA or the USCG to coordinate and direct responses under Subpart D of the NCP. It also refers to a designated representative of a lead Federal agency to coordinate and direct removal actions under Subpart E of the NCP. General responsibilities of OSCs are found in 40 CFR 300.120. OSCs are sometimes referred to as Federal On-Scene Coordinators (FOSCs).

The ***Ports and Waterways Safety Act*** (PWSA) 1972, as amended by the Port and Tanker Safety Act of 1978 (PTSA), and the Oil Pollution Act of 1990 (OPA), is designed to promote navigation, vessel safety, and protection of the marine environment. The PWSA authorizes the U.S. Coast Guard (USCG) to establish vessel traffic service/separation (VTSS) schemes for ports, harbors, and other waters subject to congested vessel traffic.

The ***Ports and Tanker Safety Act*** (PTSA) of 1978 amended the PWSA. Under the PTSA, Congress found that navigation and vessel safety and protection of the marine environment are matters of major national importance and that increased vessel traffic in the nation's ports and waterways creates substantial hazard to life, property or the marine environment. In addition, increased supervision of vessel and port operations was deemed necessary.

Preparedness is an activity, program, or system developed prior to an oil spill to support and enhance the ability of personnel and organizations to prevent, respond to, and recover from an oil spill or other adverse event.

Prevention is an on-going activity to minimize the likelihood of discharges of oil into the environment. Prevention may be a long-term approach to looking at the fundamentals of minimizing the potential of oil spills with the goal to identify, minimize, and mitigate risks.

Release means any spilling, leaking, pumping, pouring, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of oil into the environment.

Research is the systematic study directed toward fuller scientific knowledge or understanding of the subject studied. (NSF, 2009)

Response includes all activities involved in containing and cleaning up oil in order to: 1: maintain safety of human life; 2: stabilize a situation to preclude it from worsening, and; 3: minimize adverse environmental and socioeconomic impacts by coordinating all containment and removal activities to carry out a timely, effective response.

The ***Responsible Party*** (RP) of an incident is the person, business, or entity that has been identified as owning or operating a vessel or facility that caused an oil spill. The OPA definition of responsible party is codified at 33 U.S.C. § 2701 *et seq*.

Restoration is the process of restoring an affected area or resource to its pre-incident state. Restoration can take several months to many years and may require technical and financial assistance from a variety of sources. Restoration efforts are primarily concerned with actions that involve rebuilding destroyed property, re-employment of effected stakeholders, rehabilitating, replacing, or acquiring the equivalent of injured natural resources and the services they provided prior to the damage being inflicted and the repair of other essential infrastructure.

Submerged and subsurface oil refers to oil that is not floating on the water surface.

Surface Washing Agent is any product that removes oil from solid surfaces, such as beaches and rocks, through a detergency mechanism and does not involve dispersing or solubilizing the oil into the water column.

Technology is the study, development, and application of devices, machines and techniques for manufacturing and productive processes. Technology also includes tools, equipment, and methods or methodologies that apply scientific knowledge or tools. For purposes of this plan, technology represents the application of knowledge or widgets to the development and/or usage of equipment, systems and organizational capabilities for oil spill prevention, preparedness, response, and restoration.

Vessel means every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water.

EXECUTIVE SUMMARY

Title VII of the Oil Pollution Act of 1990 (OPA 90) established the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) to coordinate a comprehensive program of oil pollution research, technology development, and demonstration. Pursuant to Section 7001(b) of OPA 90, ICCOPR developed the Oil Pollution Research and Technology Plan (OPRTP) to implement the Federal research and development program.

ICCOPR published its first version of the OPRTP in 1992 and published a revised version in 1997. These two versions provided an initial baseline assessment and analysis of: agency roles and responsibilities; status of knowledge of oil pollution prevention, response, and mitigation technologies; priority research and development needs; and an estimate of resources and time needed to implement the program.

The purpose of the FY 2015-2021 version of the OPRTP, and subsequent revisions, is to provide current assessments of the oil pollution research needs and priorities. ICCOPR intends to update this OPRTP every six years to reflect advancements in oil pollution technology and changing research needs. This ongoing planning process will capitalize on the unique roles and responsibilities of member agencies to address oil pollution research and development needs and maintain awareness of research needs.

This version of the OPRTP includes two parts. Part One, Oil Pollution Research, explains why oil pollution research is needed, the parties that are involved in the research, and presents ICCOPR's Oil Pollution Research Categorization Framework for tracking research activities and successes. Part Two, Establishing Research Priorities, presents ICCOPR's priority Research Needs. It also explains the process that ICCOPR used to identify the research gaps and priorities, noteworthy oil spill events, and the current state of oil pollution knowledge. In future versions, Part One will remain relatively static; however, Part Two is expected to change significantly as research advances the state of knowledge and priority Research Needs are successfully addressed.

The Introduction and Chapter 1, The Need for Oil Pollution Research, describes the historical basis for oil pollution research and reviews trends in oil spills from different sources. ICCOPR member agencies share responsibilities to monitor changes in the oil spill system and find opportunities to improve technologies to meet changing needs. ICCOPR recognizes that activities in the Arctic and Alaska, the Gulf of Mexico, inland areas, and the Atlantic Outer Continental Shelf are all of high importance at this time.

Chapter 2, Federal Oil Pollution Research, describes the Federal entities involved in oil pollution research including the ICCOPR member agencies, other Federal research organizations and facilities. Similarly, Chapter 3, Non-Federal Oil Pollution Research Entities, describes state, industry, independent organizations, academia, and international oil pollution research entities.

Chapter 4, Structuring Oil Pollution Research, presents ICCOPR's Oil Pollution Research Categorization Framework, which provides a common language and planning framework that would enable researchers and interested parties to identify and track research in each topic area. The Framework groups research into four broad Classes: Prevention, Preparedness, Response, and Injury Assessment and Restoration. ICCOPR further classified research within each Class into 25 Standing Research Areas (SRAs), which represent the most common research themes encountered for oil spills.

Chapter 5, Knowledge Transfer and Advancement, describes ICCOPR's efforts to promote continuous improvement in the nation's ability to address oil pollution by monitoring the state of knowledge and adjusting the program to meet changing needs. The R&T planning process emphasizes and strengthens the roles and responsibilities of the member agencies to assure that research advances the capabilities to reduce oil pollution.

Chapter 6, Oil Pollution Research Needs Identification and Prioritization Process, documents the process ICCOPR employed to establish the research priorities. ICCOPR established an R&T Working Group that identified more than 900 research gaps, consolidated them into 570 unique Research Needs, and evaluated them with the assistance of the results from a survey of 280 subject matter experts.

Chapter 7, Noteworthy Oil Spill Incidents, describes important oil spill events and lists the oil pollution research gaps that they illuminated. Spills associated with vessels, drilling operations, on-shore pipelines, facilities, and railroads are included.

Chapter 8, Current State of Oil Pollution Knowledge, describes the sources and mechanisms that ICCOPR uses to obtain and share information on research needs and accomplishments.

Chapter 9, Oil Spill Research and Technology Research Priorities, presents ICCOPR's priority Research Needs. ICCOPR identified three top priorities for each SRA. For SRAs with a large number of Research Needs (i.e., Dispersants), ICCOPR established subcategories of similar research. Three priority Research Needs were assigned to each subcategory.

There are eight SRAs and 33 priorities within the Prevention Class. Two SRAs and 12 priorities are in the Preparedness Class. The Response Class has the largest number of priorities with 72 in 11 SRAs. The four SRAs in the Injury Assessment and Restoration Class have 33 priorities.

INTRODUCTION

Title VII of the Oil Pollution Act of 1990 (OPA 90) established the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) to "… coordinate a comprehensive program of oil pollution research, technology development, and demonstration among the Federal agencies, in cooperation and coordination with industry, universities, research institutions, State governments, and other nations, as appropriate, and shall foster cost-effective research mechanisms, including the joint funding of research." Section 7001(c) of OPA 90 required ICCOPR to establish a Federal oil pollution research and development (R&D) program. Pursuant to Section 7001(b) of OPA 90, ICCOPR developed the Oil Pollution Research and Technology Plan (OPRTP) to implement the Federal research and development program.

Background

Federal oil pollution research efforts began to take shape in the late 1960s following the *Torrey Canyon* oil spill off the coast of England. At that time, the U.S. had neither the technical or operational capacity to deal with a large oil spill in the marine environment (EOP-OST, 1969). The Federal government developed the first National Contingency Plan (FWPCA, 1968) to address oil spills and began extensive oil pollution research over the next 20 years. Coordination of the Federal research efforts was informal and on an ad hoc basis through conferences, workshops, and committees of researchers scheduling their projects at the Ohmsett facility. The challenges posed by the response to the *Exxon Valdez* oil spill in 1989 revealed the need for Federal agencies to better coordinate their research. Efforts to coordinate the research resulted in Title VII of OPA 90 and the first requirement for a comprehensive and coordinated research and technology plan.

ICCOPR submitted the original OPRTP to Congress in April 1992. As directed by OPA 90, ICCOPR provided the OPRTP to the National Research Council's (NRC's) Committee on Oil Spill Research and Development for review. Using input from the NRC's Marine Board, ICCOPR started a revision of the plan in May 1993 to include topics related to spill prevention, human factors, and the field testing/demonstration of developed response technologies. ICCOPR released a revised version in April 1997, which identified 21 research areas divided into three levels of priority and served as a strategic planning document for ICCOPR to communicate and coordinate research needs.

This version of the OPRTP is the first in a new series of revisions covering six-year planning cycles, and presents ICCOPR's coordinated research and technology plan for FY 2015-2021. This ongoing planning process will capitalize on the unique roles and responsibilities of member agencies to address oil pollution research and development needs and maintain awareness of research needs.

Purpose of the Plan

The 1992 version of the OPRTP provided Congress with an implementation plan for the new research and development program established by OPA 90. That version, and the 1997 revisions, provided an initial baseline assessment and analysis of: agency roles and responsibilities; status of knowledge of oil pollution prevention, response, and mitigation technologies; priority research and development needs; and an estimate of resources and time needed to implement the program. The purpose of the FY 2015-2021 version, and subsequent revisions, is to provide current assessments of the oil pollution research needs and priorities. To that end, the principal objectives of the OPRTP are to:

1. define common research themes related to oil pollution research;
2. identify on a regular basis the knowledge gaps associated with common research themes and recommend what gaps should be considered as high research priorities within them;
3. act as an umbrella or connecting document with other strategic Federal research plans (or accomplishment reports) that also address research support for oil pollution topics;
4. document the interagency research coordination process, as well as the feedback processes developed by Federal research, management and regulatory agencies; and
5. promote research information transfer between the government, the public and other stakeholders.
6. encourage and track efforts to implement improvements and technological change within agency roles and responsibilities via updates in the biennial reports to Congress.

Scope and Use of the Plan

This OPRTP provides a basis for coordinating research to address oil pollution issues in the U.S. It is primarily directed at Federal agencies with responsibilities for conducting or funding oil pollution research, but can serve as a research planning guide for industry, academia, State governments, research institutions, and other nations.

Research, in the context of the OPRTP, includes both basic and applied studies that are considered as peer-reviewed and published as well as studies reported in the "grey literature," which is publically available scientific literature that has not been peer reviewed. The following National Science Foundation definitions apply with respect to the OPRTP:

- **Basic research** is any systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.
- **Applied research** is any systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met. ICCOPR

interprets this to mean studies to advance knowledge about oil spill prevention, preparedness, response, mitigation, and restoration/recovery.

- **Development** is any systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.
- **Technology** is defined as making, usage, and knowledge of tools, machines, techniques, crafts, systems or methods of organization in order to solve a problem or perform a specific function. ICCOPR believes this definition represents the application of knowledge as well as the development and usage of the equipment, systems and organizational capabilities concerning oil spill prevention, preparedness, response, mitigation, and restoration/recovery.

At the federal level, this OPRTP provides information that can be used as a basis to conduct interagency coordination and track progress toward addressing the nation's research needs. It can also help Federal agencies:

1. identify high-priority research emphasis areas;
2. promote needed research based on priorities; and
3. synchronize and collaborate research activities to avoid overlapping research efforts.
4. track progress of key efforts to aid implementation of needed improvements.

ICCOPR recognizes that there are a large number of oil pollution research programs conducted by non-Federal organizations and the private sector. This OPRTP provides these entities with ICCOPR's recommendations on research areas that will best address the nation's oil pollution research needs.

THIS PAGE INTENTIONALLY LEFT BLANK

PART ONE – OIL POLLUTION RESEARCH

1. The Need for Oil Pollution Research

Oil is a dominant source of energy in the United States, supplying the nation with approximately 40 percent of its energy needs (Ramseur, 2012). Oil provides fuel for the transportation, industrial, and residential sectors and serves as a primary feedstock for making plastics. Oil is expected to remain a major source of energy in the U.S. for at least the next several decades. With historical, current and projected use and constant movement, it is inevitable that spills will occur.

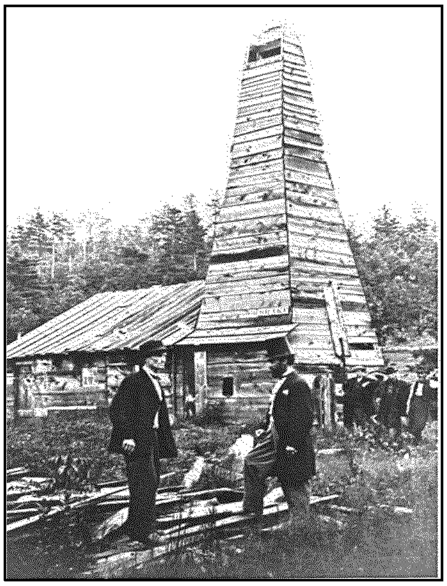


Figure 1-1: The start of the commercial oil industry in the U.S. – Oil Creek, PA, 1859 (Source: Drake Wells Museum)

Spills of oil in the U.S. accompanied the inception of early commercial efforts for petroleum drilling in the early 19th century in the United States and continue to this day. The first oil discovery was on land at Oil Creek, Pennsylvania in 1859 by George Bissel and Edwin Drake (Figure 1-1) (Pees, 2004). This success quickly led to additional commercial investments in oil drilling refining and marketing in the western Appalachian Mountains, where oil seeps were common. Commercial drilling projects rapidly spread to include areas in Southern California, Kansas, Oklahoma, Arkansas, North Louisiana and Texas by the late 1890's.

In 1910, the largest onshore blowout in the U.S. and the world occurred at the Lakeview No. 1 well in the San Joaquin Valley, CA (Figure 1-2). The initial flow estimates ranged from 125,000 barrels per day (bpd) at the start to 90,000 bpd after a month. The well remained uncontrolled for 544 days with an estimated 9.4 million bbl of crude being released into the environment (one barrel = 42 U.S. gallons).

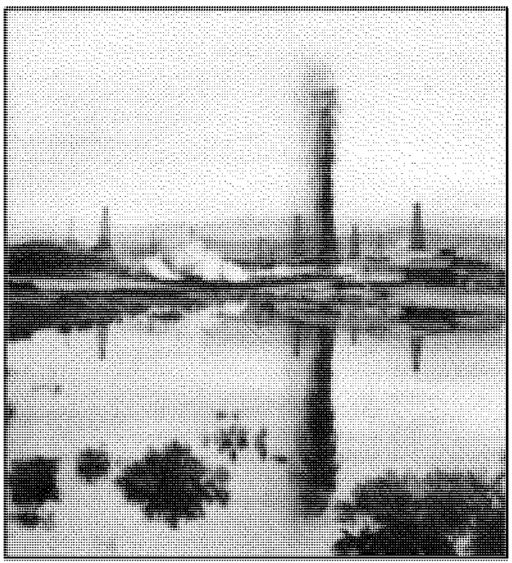


Figure 1-2: The Lakeview Gusher, CA; the US's single largest well blowout, 1910. (Source: San Joaquin Valley Geology)

Oil spills continued to occur but it wasn't until the late 1960s that the national attention focused on the need to address the problems associated with oil spills. In 1967, reaction in the U.S. to the *Torrey Canyon* oil spill off the coast of England resulted in the creation of the original National Multiagency Oil and Hazardous Materials Contingency Plan in 1968 (FWPCA, 1968). That Plan was superseded in 1970 when the Council on Environmental Quality (CEQ) published the National Oil and Hazardous Materials Pollution

Contingency Plan in the Federal Register at 35 FR 8508 (CEQ, 1970). In 1969, a well blowout and undersea faults spilled an estimated 42 million gallons of oil into the Santa Barbara Channel, one of the largest environmental disasters in the U.S. (NOAA, 2014). This spill increased awareness of oil pollution problems and contributed to creation of the U.S. Environmental Protection Agency, the National Environmental Policy Act, and the National Marine Sanctuaries system. It also prompted several federal agencies to begin oil pollution research programs.

Oil pollution research must continually evolve to keep pace with new oil spill risks and environments where they occur. The process by which oil is produced, processed, and delivered to consumers is ever evolving. The oil industry opens new areas for exploration and production as technological advances make the ventures profitable. In turn, the location and methods of transporting that oil to markets shifts, affecting the potential locations and types of oil spills. For example, the opening of the Alaska North Slope and the Trans-Alaska Pipeline necessitated transportation of crude oil by tanker through Prince William Sound, site of the *Exxon Valdez* oil spill. Similarly, the technological advances that allow deep water oil exploration and production also pose new hazards and risks as evidenced by the British Petroleum (BP) *Deepwater Horizon* oil spill. Those spills posed new response challenges and revealed the need for additional oil pollution research.

There will continue to be a need for oil pollution research as long as there is a demand for oil-based products. Human errors, mechanical failures, natural events, and accidents all have the potential to cause spills. This chapter examines the oil production system and patterns of oil spills that affect the oil pollution research needs addressed in this OPRTP.

1.1 U.S. Oil Production

Figure 1-3 shows the U.S. Energy Information Administration (EIA) Annual Energy Review 2015 (EIA, 2015) and provides a review on the production, import and consumption for petroleum and other liquids for the last 60 years (from 1949 to 2014). The U.S. has experienced a steadily increasing consumption rate that quickly outstripped the U.S. petroleum production capabilities, resulting in a regular increase in net imports of petroleum products to address the shortfall beginning in 1970. Domestic production of oil continued to decrease until 2008 when new finds and improved drilling capabilities began to increase U.S. field production.

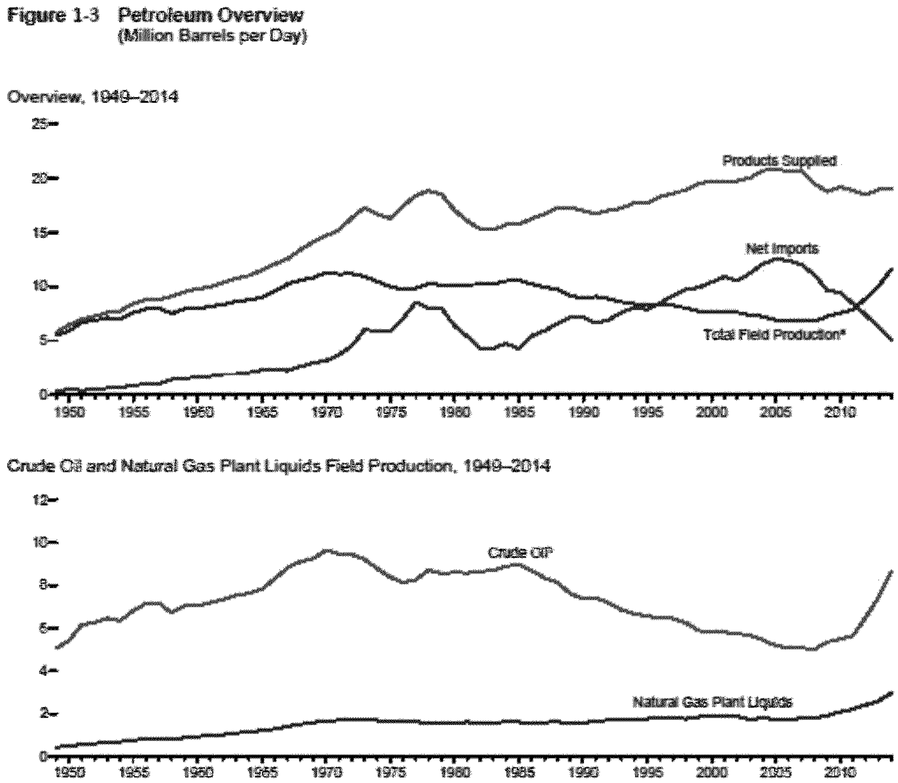


Figure 1-3. Petroleum and other Liquid Estimated Consumption, Production and Net Imports (in million bod) for 1949 – 2014 in the U.S. Source: EIA. 2015.

Of particular note was the discovery of the Bakken field in North Dakota, Montana and in Canada (Figure 1-4). Significant increases in domestic production from these discoveries resulted in a decrease in net oil imports as shown in Figure 1-3. The increase in production of natural gas has also led to a decrease in net imports. The application of hydraulic fracturing and horizontal drilling technologies caused a significant increase in Bakken production since 2000. By the end of 2010, oil production rates had reached 458,000 bbls per day, outstripping the pipeline capacity to ship oil out of the Bakken. The result was an expansion of rail transportation to move the crude oil to refineries or ports for export.

Shale oil and natural gas resources are found in shale formations that contain significant accumulations of natural gas and/or oil (Figure 1-4). The Barnett Shale in Texas has been producing natural gas for more than a decade. Information gained from developing the Barnett Shale provided the initial technology template for developing other shale plays in the U. S. Another important shale gas play is the Marcellus Shale in the eastern U. S. While the Barnett and Marcellus formations are well-known shale gas plays in the United States, more than 30 U.S. states overlie shale formations. The Marcellus natural gas trend, which encompasses 104,000 square miles and stretches across Pennsylvania and West Virginia, and into southeast Ohio and upstate New York, is the largest source of natural gas in the United States, and production was still growing rapidly as of 2014.

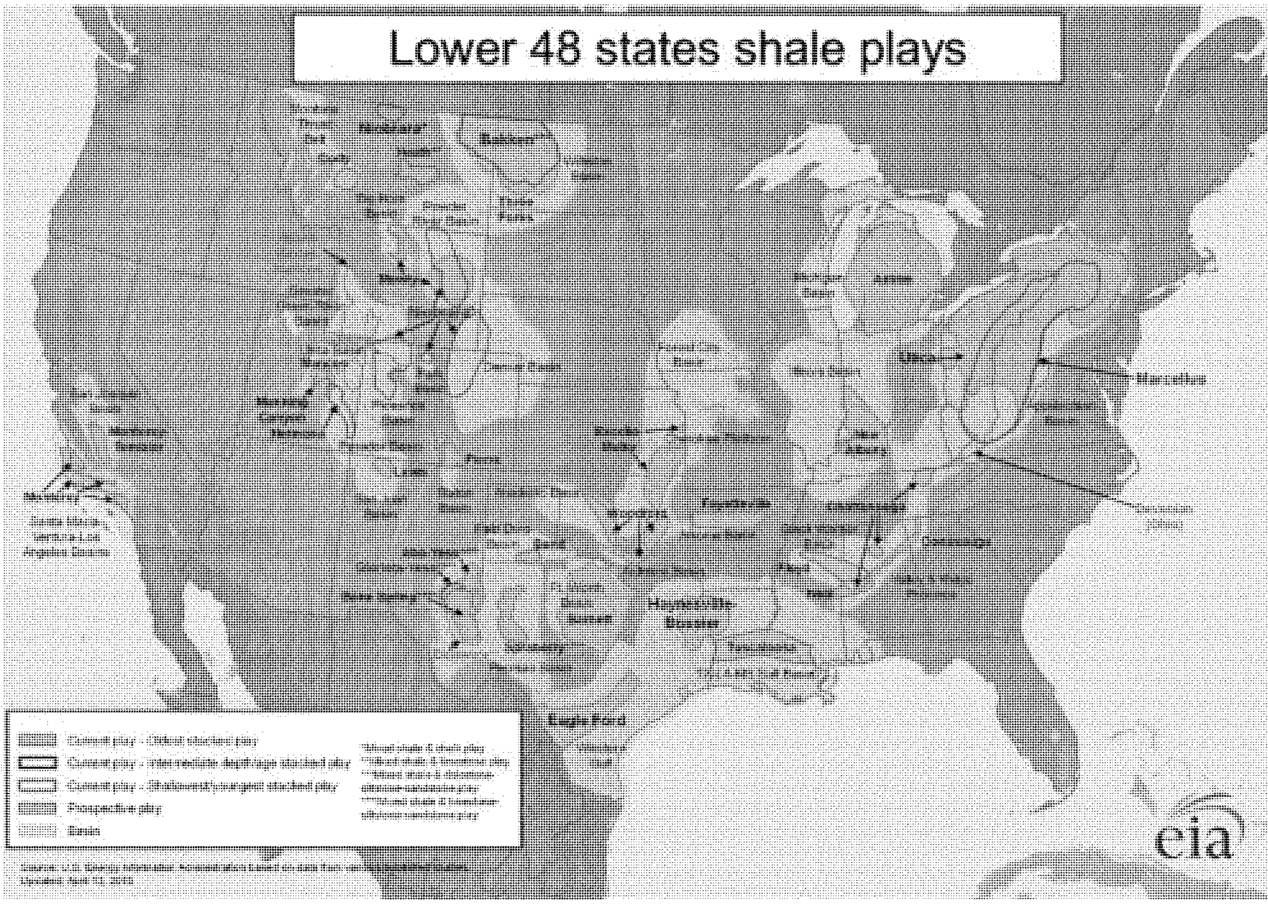


Figure 1-4 Domestic Shale gas plays. Source: EIA 2015

Figure 1-5 shows the location of refineries in the U.S. Figure 1-6 shows the substantial increase in transportation of petroleum from the Midwest to other parts of the country where the refinery capacity exists. The greatest overall volumes were transported to the Gulf coast. The 2010 to 2014 period reflects the increase in U.S. production in the shale-producing locations.

The significant increase in petroleum being transported within the U.S. has taxed the available pipeline capacity significantly. In order to meet some of the increased demand, there has been a significant increase in rail transportation of crude oil.

The large increase in U.S. and North American petroleum production has resulted in a significant change in the transportation patterns. The production from the Bakken field and the Canadian oil sands products (OSP) areas have resulted in a significant change in the number trains and tank cars carrying petroleum. The Association of American Railroads (2015) reports that the number of rail tankers carrying crude oil and petroleum products in the U.S. increased from just under 19,000 carloads in 2008 to more than 1,033,000 carloads in 2014. Figure 1-7 shows the change in the number of rail cars and the change in train movements between 2010 and 2014; this represents the time period when the development of Bakken oil began to be significant.

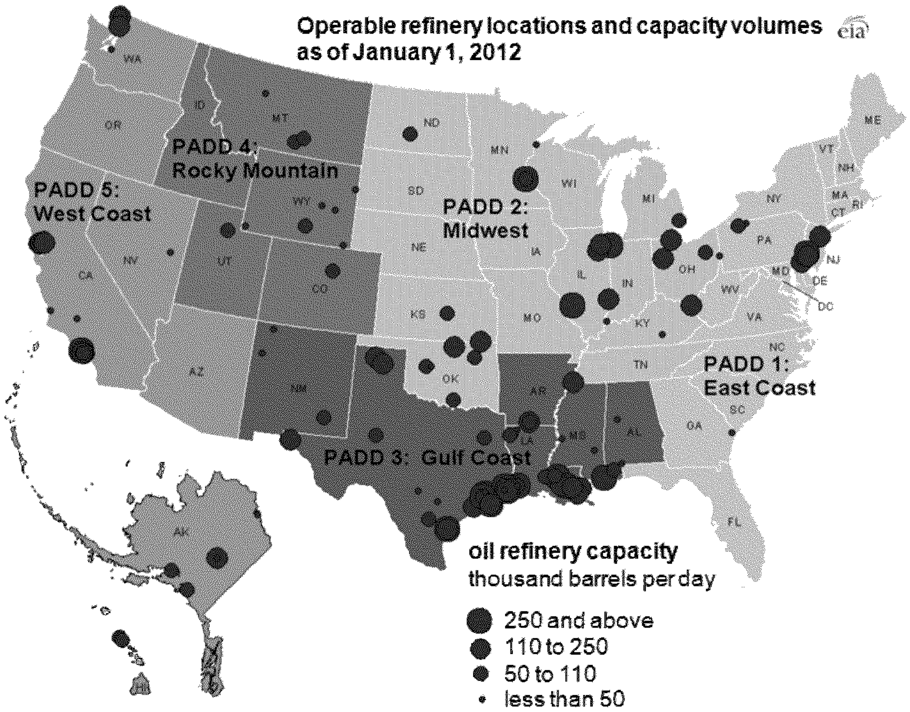


Figure 1-5: Location of U.S. Refineries and Refining Capacity. EIA 2015.

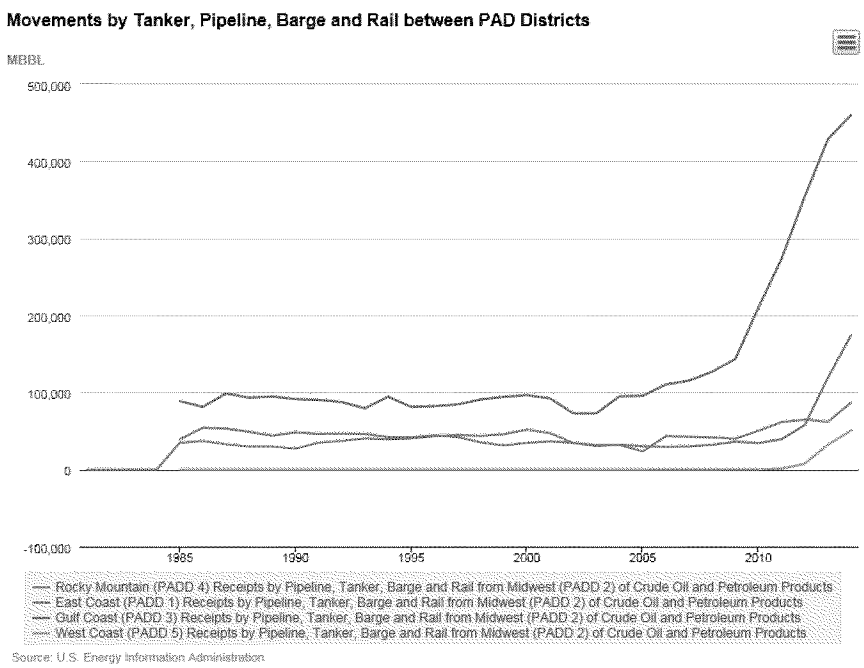
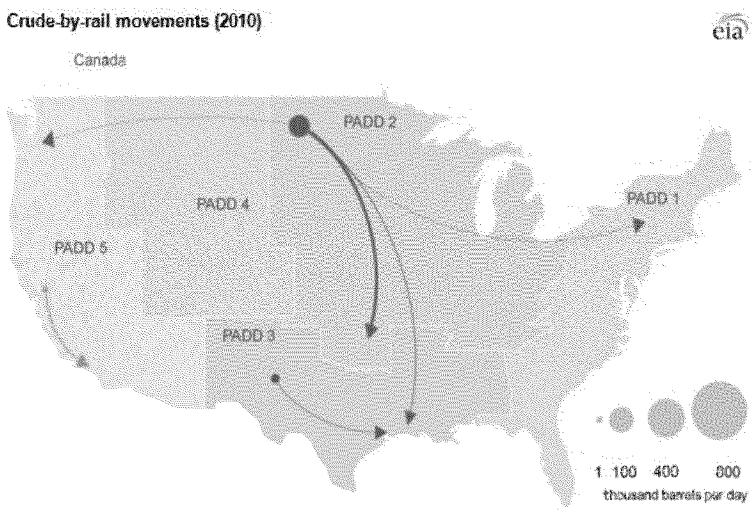


Figure 1-6 Movement of crude oil (MBBL) by pipeline, tanker barge and rail tor refinery areas. Source: EIA 2015.



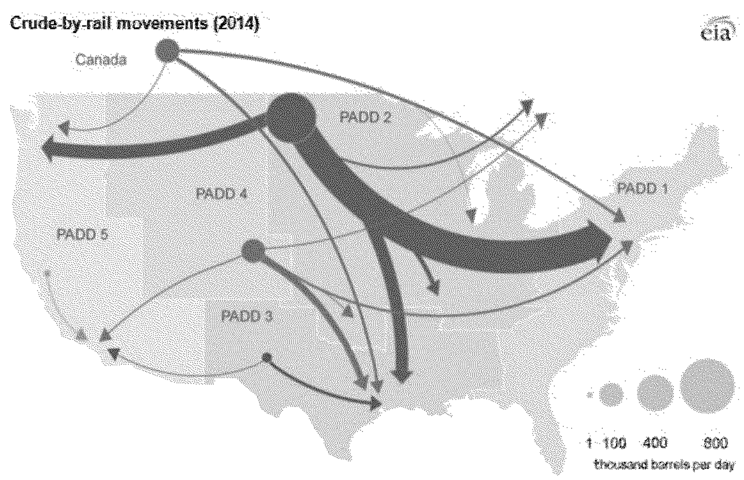
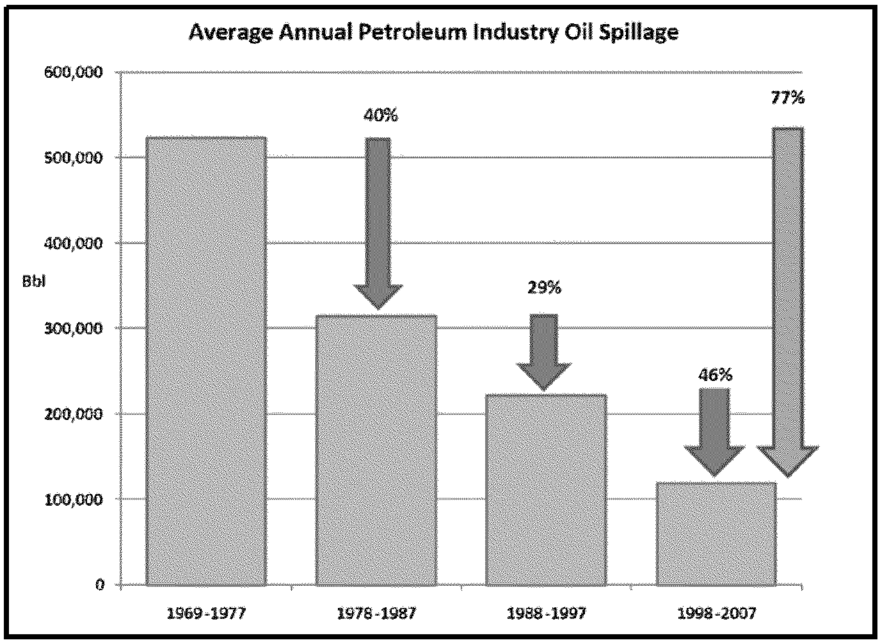


Figure 1-7 A comparison of crude oil movements by rail from 2010 and 2014. Source EIA 2015.

1.2 History of Oil Spills in the U.S.

From 1973 to 1990, an average of 2.8 million bbl of oil was spilled every year. Since 1990, that number has reduced to 35,700 bbl a year. Based on data between 1973 and 2009, the annual number and volume of oil spills declined, and in some cases dramatically (Etkin, 2009). Total petroleum industry spillage has decreased consistently over the last 40 years through 2007 (Figure 1-8). Table 1-1 summarizes the average annual oil spillage from petroleum industry sources, including: spillage related to oil exploration and production platforms and offshore pipelines; spillage from coastal and inland pipelines, tank vessels, railroads, and tanker trucks; spillage from oil refineries; and spillage at gas stations. By multiplying the average annual spill volumes for each decade by 10, the total volume spilled (as recorded) from 1969 to 2007 would approximately equal 17.5 million bbls. (See Table 1-1.)



*NOTE: The average annual oil spillage volumes represented here are gathered from petroleum industry spillage sources, including: spillage related to oil exploration and production, platforms and offshore pipelines; spillage from coastal and inland pipelines; spillage from oil transport by tank vessels, railroads, and tanker trucks; spillage from oil refineries; and spillage from gas stations.

Figure 1-8: Average Annual Oil Spillage from Petroleum Industry Sources by Decade. Etkin, 2009.

These figures do not address any other significant spillage events in the U.S. after 2007, which would include the 2010 Macondo/*Deepwater Horizon* (DWH) well blowout and oil spill and the 2010 Enbridge Pipeline release in the Kalamazoo River in Michigan or any other significant spillage events in the U.S. after 2007. The 4.9 million bbls spilled during the *Deepwater Horizon* oil spill (USCG, 2011b) would reverse this downward trend and increase the total volume spilled between 1969 and 2007 by nearly 1400 percent; this incident represents nearly 95% of the total volume spilled from all oil platforms in the last 42 years. In general, the very largest spills, which constitute only 0.4% of the total spills, comprise 90.6% of the total volume spilled in the U.S. for the period 1988 – 2007.

Average Annual Oil Spillage from Petroleum Industry Sources, bbls. Modified From Etkin, 2009				
Source	1969-1977	1978-1987	1988-1997	1998-2007
PRODUCTION	31,435	8,701	15,183	9,938
Offshore Platform Spills	25,858	1,344	1,814	1,273
Offshore Pipelines	4,48	3,462	8,127	2,614
Offshore Supply Vessels	95	245	48	10
Inland Production Wells	1,000	3,650	5,194	6,041
REFINING	3,000	3,512	15,015	12,136
Refinery Spills	3,000	3,512	15,015	12,136
TRANSPORT	488,662	301,645	190,753	96,393
Inland Pipelines	259,340	181,196	118,297	76,754
Tanker Trucks	3,000	4,888	5,213	9,181
Railroads	2,000	2,322	2,164	1,431
Tank Ships	192,492	60,250	42,197	3,598
Tank Barges	31,830	52,989	22,882	5,429
STORAGE AND CONSUMPTION	118,523	97,206	278,525	77,613
Non-Tank Vessels (Cargo Ships)*	5,000	6,786	2,817	1,602
Other Vessels*	14,858	6,574	6,301	4,167
Gas Stations and Truck Stops	1,195	1,195	1,564	814
Residential*	150	179	518	498
Aircraft*	3,700	3,714	3,862	4,044
Inland EPA-Regulated Facilities*	30,000	34,740	245,017	59,676
Coastal Facilities (Non-refining)*	62,220	42,781	15,059	4,230
Inland Unknown*	900	967	2,198	516
Motor Vehicles*	500	270	1,189	2,066
AVERAGE ANNUAL TOTALS	641,620	411,064	499,476	196,080
ESTIMATED DECADE TOTAL	6,416,200	4,110,640	4,994,760	1,960,800
ESTIMATED GRAND TOTAL SPILLAGE for 1969 – 2007	17,482,400 bbls (734,560,800 gallons)			
*Additional storage and consumption data for the 1969-1977 period was provided by Dagmar Schmidt Etkin, 2011, personal communications.				

Table 1-1: Average Annual Oil Spillage from Petroleum Industry Sources, bbl. (Modified from Etkin, 2009).

1.3 Analysis of the Oil Spill System

In their Congressionally-mandated review of the 1992 OPRTP, the National Research Council (NRC) Marine Board recommended "…an analysis of the marine oil spill system, which consists of a variety of subsystems beginning with drilling for oil and ending at delivery of the product to the consumer." The oil spill system described by the NRC consists of all components and nodes of the oil supply chain (see Figure 1-9) including all aspects of the oil handling and transport processes, succeeding environments affected as a spill spreads, and intervention techniques for preventing or minimizing environmental damage (Marine Board, 1993; 1994). The NRC advocated that such an approach would identify critical nodes of potential failure within the system where ICCOPR could focus its research planning efforts.

ICCOPR agreed with the NRC on the value of a systems analysis approach in research planning but full implementation of the approach has been beyond the funding capabilities of the ICCOPR membership. In 2007, the USCG Research & Development Center (RDC) completed a system analysis of the response system and used the results to identify and evaluate research opportunities as part of strategic planning to improve spill response (VanHaverbeke, 2012). ICCOPR member agencies also have expertise on specific components of the oil spill system. This base of knowledge on the system components provides a general framework from which ICCOPR plans its research coordination, funding allocations, and measures of effectiveness. The oil spill research categorization scheme discussed in Chapter 4 reflects how ICCOPR used its understanding of the oil supply chain and oil spill response system to focus research planning as envisioned by the NRC.

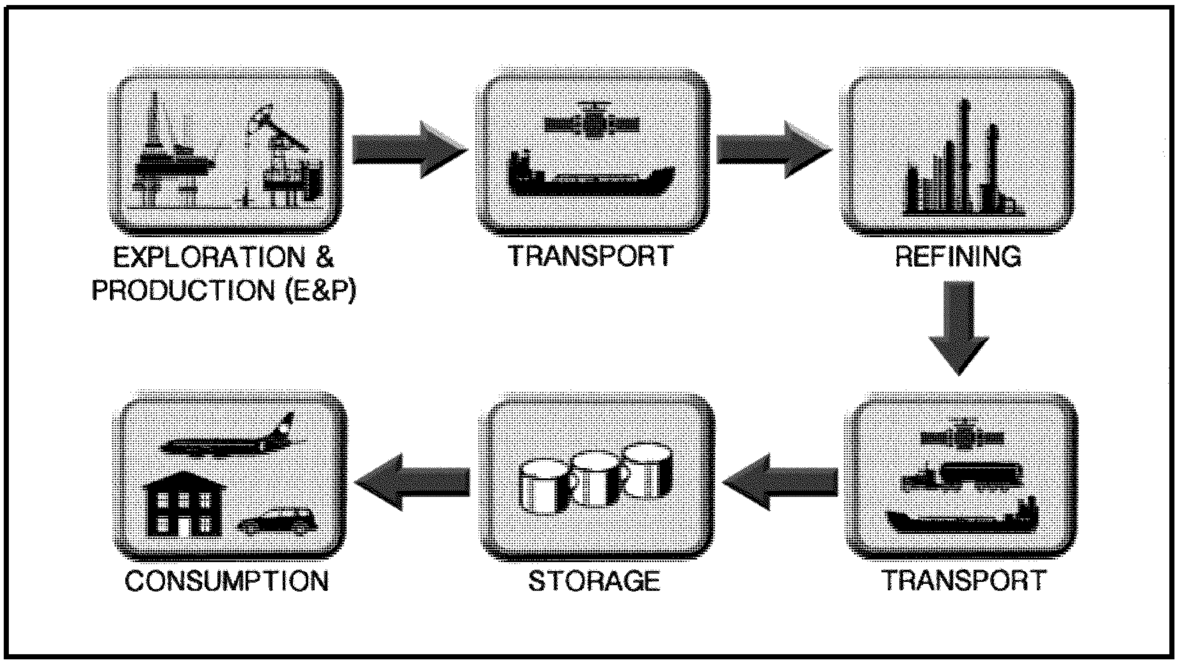


Figure 1-9: Oil Supply Chain.

For planning R&D activities, the oil supply chain for petroleum oils consists of five subsystems (Figure 1-9):

- **Subsystem 1-Exploration and Production Facilities** - This is the origination point of crude oil and includes onshore and offshore exploration and production facilities.
- **Subsystem 2-Transportation** - This is the transportation of foreign and domestic oil products (generally crude oil) to refineries in the U.S. either by tank vessel (ship and barge), pipeline (offshore and onshore), tank railcar (unit trains), or tanker trucks.
- **Subsystem 3- Refining** - Refining of crude oil into petroleum products including the storage of crude oil, actual refining operations, storage of refined products, and the loading of refined products on tank vessels (ship and barge), tank railcars, and tanker trucks. In addition, refining would also encompass those activities that produce biofuels or vegetable oils. The latter products present many common and novel challenges compared to their traditional petroleum counterparts.
- **Subsystem 4- Transport / Storage/Distribution** - This subsystem involves the transportation of refined products to a bulk distribution storage facility by various modes of transportation, (e.g., product pipeline, tank vessel (ship and barge), tanker truck, tank railcars). Imported refined products would enter the U.S. system, as well as exported refined products would leave the U.S. system at this point. Tanker trucks may also deliver direct from refinery storage to the end user, e.g., residence or retail gas station.
- **Subsystem 5-Consumption/Consumer/Retail/Industrial** - This subsystem includes the retail gas station and the residential home heating oil segments of the oil system as well as industrial users (e.g. electric generation facilities).

There are available historic data to support claims that the improved safety and operating procedures implemented have generally reduced the risk of a spill at any point along the system. However, because accidents cannot be completely eliminated, efforts to improve pollution prevention and response must be sustained. In the following section, five potential high risk spill sources (exploration & production, vessels, onshore and offshore pipelines, railroads and refineries / bulk terminals) are examined to highlight existing weaknesses and concerns, and the efforts being made to address them.

1.4 Exploration and Production Facilities

The spill record for domestic drilling and production over the past 30 years suggested that technology and procedures for preventing oil spills were being employed effectively. However, that trend was interrupted in 2010 when the DWH drilling rig experienced an uncontrollable well blowout and oil spill. Even with modern equipment and modern safety measures, spills are a part of the oil and gas industry. The DWH blowout occurred when human errors circumvented the modern technological safeguards designed to prevent such an accident.

> "Current technology enables drilling in water twice as deep as Macondo. Drilling at such depths requires all parties to set their standards still higher for difficult issues such as remote containment systems in water depths with extreme pressures and very limited human access, as well as different geological pressures and formations and mixes of hydrocarbons. Desire to tap resources in deeper waters should be accompanied by equivalent investments in subsea equipment, operator training, research and development for containment and response technologies, demonstrated financial capacity, and continuous improvement in and communication of industry practices devoted to safety." *(National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011)*

Due to the rising energy demands in developed economies and dramatically rising levels of consumption in emerging economies, the world's appetite for oil and other fuels will continue growing for the foreseeable future. This demand will increase pressure for continued and new oil and gas exploration in challenging environments including in the Arctic and in deep and ultra-deep waters. It will also encourage exploration and production of unconventional resources (e.g., oil sands) and the increased use of advanced technologies (e.g., hydraulic fracturing and horizontal drilling).

1.5 Onshore and Offshore Pipelines

Approximately 2.6 million miles of pipelines provide an efficient and fundamentally safe means of transporting gases and liquids. They are an integral part of the U.S. energy supply and provide vital links to other critical infrastructure such as power plants, airports, and military bases. Currently, there are 199,157 miles of pipelines that carry volatile, flammable, or toxic materials with the potential to cause public injury and environmental damage.

Canadian oil exports to the U.S. have been increasing rapidly, primarily due to growing extraction from the oil sands in Western Canada. Oil sands are a mixture of clay, sand, water, and heavy black viscous oil known as bitumen. After extraction, the bitumen is converted into an oil sands product (OSP) suitable for pipeline transport. Canada's OSPs are exported as either light, upgraded synthetic crude ("syncrude") or a heavy crude oil that is a blend of bitumen diluted with lighter hydrocarbons ("dilbit") to ease transport. The bulk of oil sands' supply growth is expected to be in the form of dilbit.

The expansion of petroleum pipelines from Canada has generated considerable controversy in the U.S. One specific area of concern was the potential new risks of the OSPs to pipeline integrity. An NRC panel (TRB, 2013) concluded, however, that diluted bitumen does not have any unique properties that make it more likely to cause internal failure of pipelines than other types of crude oil. However, additional research is needed to understand the fate and transport of unconventional oils, relative to that of traditional crude oils and refined products.

In the 49 year period between 1964 and 2012, there were 79 oil spills from pipelines on the Outer Continental Shelf according to BSEE (2015) statistics, or about 1.6 per year. However, 25 of those spills were caused by damage from a series of hurricanes in the Gulf of Mexico in 2004, 2005, and 2008. Otherwise, spills from offshore pipelines occur at a rate of about one per year.

Both government and industry have taken numerous steps to improve pipeline safety over the last 10 years such as improved corrosion resistance, integrity testing, and requirements to identify pipelines before digging. According to PHMSA, pipelines are extremely safe when compared to other modes of energy transportation relative to the volumes of products transported (PHMSA, 2007). The trend is down, however, major pipeline incidents in 2010 and 2011 suggest that more work is needed. Figure 1-10 and Table 1-2 provide information from PHMSA on pipeline oil spills over the past 20 years.

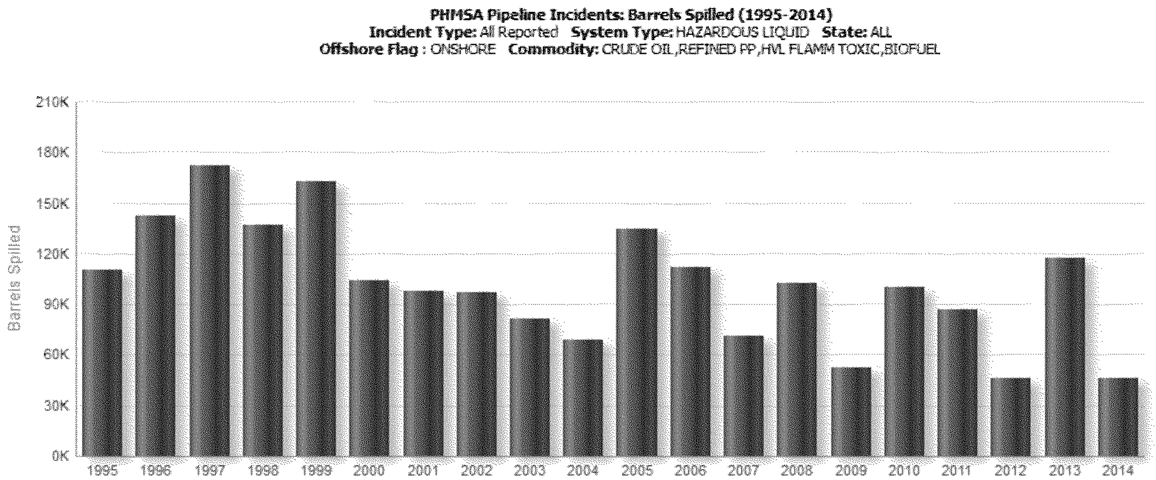


Figure 1-10 Barrels of Oil Spilled by Pipelines (1995-2014)

PHMSA Pipeline Incidents: (1995-2014)
Incident Type: All Reported **System Type:** HAZARDOUS LIQUID **State:** ALL
Offshore Flag : ONSHORE **Commodity:** CRUDE OIL,REFINED PP,HVL FLAMM TOXIC,BIOFUEL

Calendar Year	Number	Fatalities	Injuries	Property Damage As Reported	Barrels Spilled	Net Barrels Lost
1995	176	0	9	$31,575,189	109,865	0
1996	180	3	7	$74,543,311	141,994	0
1997	155	0	2	$40,836,392	171,988	0
1998	133	1	5	$52,048,979	136,760	0
1999	151	4	17	$81,722,760	162,637	0
2000	131	1	4	$130,605,839	103,806	0
2001	121	0	9	$24,684,499	97,852	0
2002	442	1	0	$49,258,448	96,809	0
2003	421	0	0	$67,314,774	81,292	0
2004	355	5	16	$83,996,433	68,840	0
2005	340	2	2	$275,460,922	134,614	0
2006	326	0	2	$52,848,585	112,029	0
2007	321	4	9	$59,509,192	71,032	0
2008	360	2	2	$136,858,894	101,940	0
2009	325	0	1	$58,112,827	52,437	0
2010	340	1	4	$1,066,323,312	100,223	49,116
2011	339	1	2	$268,056,467	86,490	54,832
2012	359	3	4	$143,694,837	45,861	29,315
2013	392	1	5	$276,271,799	117,415	85,799
2014	438	0	0	$101,402,847	45,975	20,612
Grand Total	**5,805**	**29**	**100**	**$3,075,126,306**	**2,039,859**	**239,675**

Table 1-2, PHMSA Pipeline Spill Statistics (1995-2014)

1.6 Railroads

New technologies and high global oil prices have made it economical for energy companies to develop shale oil and oil sands petroleum reserves in the United States and Canada. The challenge is getting the oil from the oil fields to the appropriate refineries across North America so they can process the oil. That has created an opportunity for railroads to fulfill the transportation demand. In 2011, railroads and other facility and transportation businesses began building loading facilities and adding tank cars to compete with pipelines for a piece of this transportation demand.

The movement of Bakken oil and OSP occurs via unit trains, which can be composed of more than 100 tank cars, all carrying the same cargo. Tank cars are typically double-lined and made of hardened steel to survive a derailment. With the increased use of unit trains there has been an increase in the number of significant spills from derailments.

The American Petroleum Institute's Analysis of U.S. Oil Spillage (Etkin, 2009), which tracks oil spill statistics up through 2007 data, stated that railroads spilled 1,400 bbl of oil annually as cargo in tank cars and as fuel. This was a 34% reduction from the previous decade (1990s). The Association of American Railroads (2015a,b) reports that the number of rail tankers carrying crude oil and petroleum products in the U.S. increased from just under 19,000 carloads in 2008 to more than 1,033,000 carloads in 2014. The Federal Railroad Administration (FRA) statistics indicate number of train accidents has continued to decrease from 2005-2014 (Table 1-3). The number of hazmat releases has decreased also over this time period, although the level of damages over $1 million dollars has remained constant. However, the increased transportation of crude oil resulted in a number of significant rail accidents that resulted in damages and deaths. (See section 7.1.5)

In 2014, the U.S. Department of Transportation (DOT) began a comprehensive rulemaking proposal to improve the safe transportation of large quantities of flammable materials by rail - particularly crude oil, denatured alcohol, and ethanol/gasoline mixtures - because of the concern for the quantity of Bakken crude transported by rail and the increase in number of accidents. DOT proposed enhanced tank car standards, a classification and testing program for mined gases and liquids, and new operational requirements for high-hazard flammable trains that include braking controls and speed restrictions. Within two years it proposes the phase out of the use of older DOT 111 tank cars for the shipment of packing group I flammable liquids, including most Bakken crude oil, unless the tank cars are retrofitted to comply with new tank car design standards.

Category(1)	CY05	CY06	CY07	CY08	CY09	CY10	CY11	CY12	CY13	CY14
Freight Train Accidents(2)	3266	2998	2693	2481	1912	1902	2022	1760	1822	1736
Hazmat cars Damaged or Derailed (3)	915	1041	1056	750	743	708	665	671	822	779
Hazmat Releases(4)	39	30	46	21	22	21	21	26	18	15
Cars Releasing	52	71	76	37	44	40	66	50	78	26
Damages >100k	526	571	540	481	385	423	407	347	406	381
Damages >1mil.	57	59	69	52	52	57	53	43	66	58
Deaths	33	6	9	27	4	8	6	9	11	2

(1) Calendar years
(2) Not including crossing collisions and other accidents with death
(3) Total hazard material cars damaged
(4) Accidents with hazard material releases

Table 1-3: Number of Train Accidents and Hazmat Releases 2005-2014. (FRA 2015)

1.7 Refining and Storage Operations

Potentially damaging discharges of crude oil or petroleum products in a refinery or at a bulk storage terminal can and do occur at every point in this system (offloading, storage, loading), and the factors that can influence the occurrence of these accidental discharges includes: the design, construction, maintenance, and operational activities; and human factors (e.g. training).

Despite a decrease in the number of domestic refineries between 1982 and 2010, the U.S. combined daily throughputs have slowly increased from about 12 million up to approximately 15 million bbl/day (Table 1-4). Increased throughput has occurred in spite of decreased numbers of refineries, because remaining refineries operate at increased capacities/efficiencies to compensate for the lack of production at decommissioned older refineries.

U.S. Gross Inputs to Refineries (Thousands of Barrels per Day)										
Decade	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
1980s						12,165	12,826	13,003	13,447	13,551
1990s	13,610	13,508	13,600	13,851	14,032	14,119	14,337	14,838	15,113	15,080
2000s	15,299	15,352	15,180	15,508	15,783	15,578	15,602	15,450	15,027	14,659
2010s	15,177	15,289								
Source: U.S. Energy Information Administration (EIA), 2012.										

Table 1-4: U.S. Gross Inputs to Refineries (Thousands of Barrels per Day)

Thousands of above ground crude oil and refined product storage tanks are in service at refineries and other oil/product handling/storage facilities. Buried pipelines within refinery boundaries represent another source of leaks. Aging domestic refinery infrastructure increases the risk of spillage and better systems are needed to detect potential problems. Another possible source of leakage is the refinery process line.

On June 19, 2006, a violent rain storm compromised a waste oil tank at the CITGO Refinery on the Calcasieu River, near Sulfur, Louisiana. Oil booms initially contained the spilled oil but subsequently failed and oil spread down the Calcasieu River and into Calcasieu Lake. The spill released up to an estimated 71,000 bbls (approximately 3 million gallons) of waste oil into the environment. The exact amount of oil spilled and the amount reaching the water is still unknown. Hurricane Katrina also caused considerable damage and oil spills from the refineries and bulk storage terminals in the storm's path (Table 1-5).

Spill Events that Occurred in the Path of Hurricane Katrina (2005)	
Spill Location	**Quantity (bbls)**
Bass Enterprises (Cox Bay)	90,000
Shell (Pilot Town)	25,000
Chevron (Empire)	23,600
Murphy Oil (Meraux and Chalmette)	19,500
Bass Enterprises (Pointe à la Hache)	10,980
Chevron (Port Fourchon)	1,260
Venice Energy Services (Venice)	595
Shell Pipeline Oil (Nairn)	320
Sundown Energy (West Potash)	310
Source: Pine, 2006	

Table 1-5: Spill Events that Occurred in the Path of Hurricane Katrina (2005).

1.8 Maritime and Riverine Transport - Tank Vessels (Ships & Barges) and Non-Tank Vessels

A combination of Federal, State, and international authorities are responsible for regulating oil spills from vessels in the U.S. They are collectively responsible for creating and implementing legislation to prevent oil spills and handling the decisions and procedures that follow in the aftermath.

There has been a reduction of operational and accidental oil spillage in the U.S. that can largely be attributed to the domestic and international regulations that have improved shipping safety and increased limits of liability for oil spills. These regulations required the phase-out of single hull tank vessels (ships and barges) and development of new tank vessels designs for double hulls to reduce accidental discharges in the event of grounding, collision, and allisions. Operational preventative measures including mandatory tug escorts for tank ships transiting through environmentally-sensitive areas in ports may also have contributed to the downward spillage trend by ensuring immediate assistance to a vessel experiencing a loss of propulsion or steerage.

Section 703 of the Coast Guard Authorization Act of 2010 directed the USCG to conduct a study of oil spills involving commercial vessel sources between 2001 through 2010 (Table 1-6). The Coast Guard released the study in May 2012 and reported that a small number of vessel casualties resulted in the greatest percentage of the overall spill volume. The data also show that most spills do not involve vessel casualties. These non-casualty spills are termed "operational" spills. The report addressed casualty and non-casualty groupings separately in order to identify their respective causal factors. The report defined a non-casualty spill as one in which the only reported occurrence is an oil spill (i.e., the incident did not involve an allision or collision).

U.S. Oil Spills from Vessels – 2001 - 2010. From: USCG, 2012		
Vessel Type	**Spills**	**Barrels**
MODU*	259	9,842
Tank Barge	1,318	75,044
Tank Ship	426	30,070
Freight Ship	893	17,284
Fishing Vessel	3,619	8,746
Tow / Tugboat	2,965	6,956
Public Vessel	486	3,077
OSV / Oil Recovery	883	2,334
Recreational	5,058	1,696
Unclassified Vessel	2,479	1,511
Passenger	1,100	8,66
Industrial Vessel	604	675
Freight Barge	407	408
Research Vessel	162	107
Other	51	11
TOTALS	**20,710**	**158,633**

*MODU- Mobile Offshore Drilling Units

Table 1-6: U.S. Oil spills from vessels 2001-2010. (USCG, 2012)

The study concluded that the most frequently reported human factors were inattention, procedural errors and situational awareness. However, while the study focused on human factors, it found that more than half of all discharges were the result of material failure. Vessel casualty statistics showed that the combination of material failure and loss of vessel control led to some of the largest oil spill volumes from 2001 through 2010. Material failure was a significant factor for propulsion and steering problems. The potential for damage due to allision, collision, or grounding is significant when such failures occur on large vessels, (e.g. tank ships, freight ships). According to industry feedback, material failures are also a significant factor in near-miss incidents.

1.9 Oil Tankers

Stricter regulations and improved operations of oil tankers has reduced the number of large (> 5,000 bbls, or 7 tonnes) and medium (50 – 5,000 bbls) oil spills from tankers globally, as well as in the U.S. despite an increase in marine transportation of oil. Following the grounding of the single-hull tank vessel *Exxon Valdez*, OPA 90 mandated that all newly built tank vessels have double hulls and that single-hull tank vessels be phased out and replaced by double-hulled vessels by January 1, 2015 for operations in the U.S. waters. Similarly, requirements stemming from the International Convention for the Prevention of Pollution from Ships (MARPOL) have increased the safety of tanker transport.

The International Tanker Owners Pollution Federation Limited (ITOPF), which tracks oil spills from tankers, reports that 19 of the 20 largest spills from tankers occurred before 1970 (ITOPF, 2015). Figure 1–11 shows the trend in oil tanker transport and the number of spills. Figure 1-12 shows the downward trend in oil spills from tankers since 1970 according to ITOPF.

Figure 1-11: Seaborne oil trade and oil spill trends

ED_001324_00001035-00048

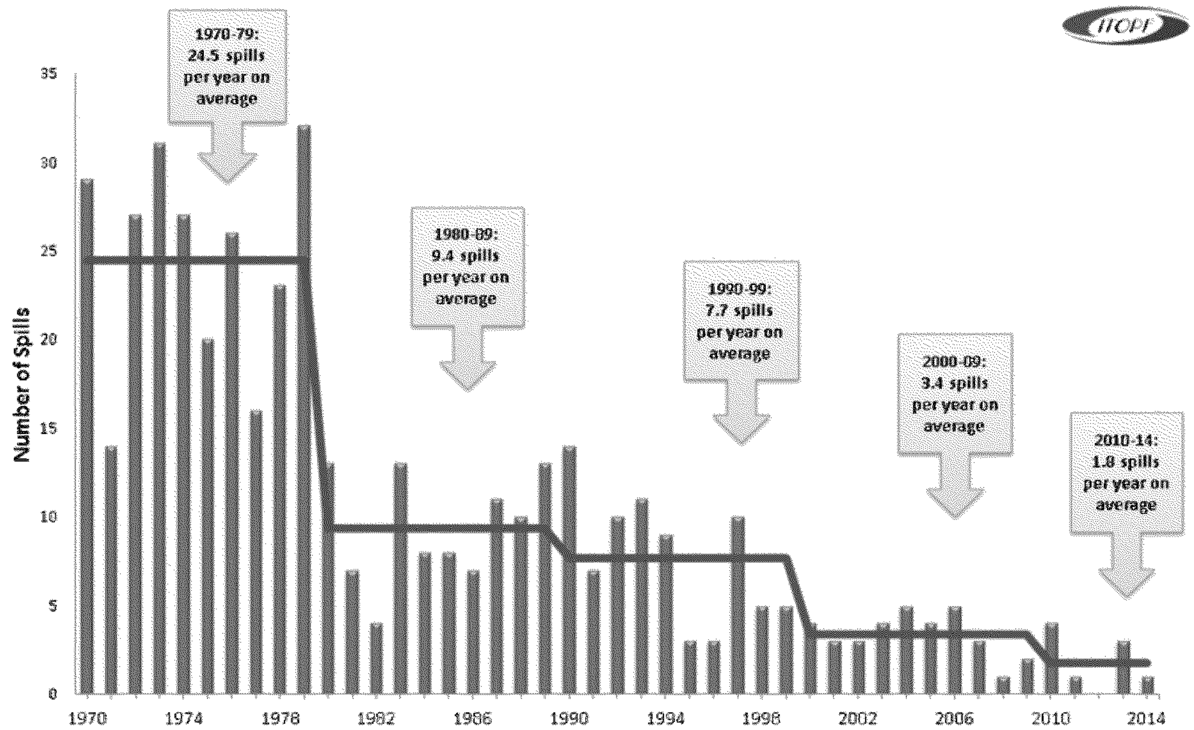


Figure 1-12: Number of Large Spills (>5,000 bbls) from 1970-2014 (ITOPF, 2014)

1.10 Regional and Geographic Areas of Interest

ICCOPR considers regional issues an important element in executing an effective oil pollution R&T program. The applicability of research results can vary significantly between geographic regions due to their unique environmental characteristics. Regional issues are prevalent in the Arctic with its potential for new oil exploitation and related activity, and in the Gulf of Mexico where ultra-deepwater drilling and injury assessment and restoration activity from the *Deepwater Horizon* spill continues. Inland regions, likewise, have evolving issues related to onshore shale oil, oil sand products development, and pipeline and rail transportation safety. Development of other OCS regions will raise their own geographically-specific issues. In its research planning efforts, ICCOPR maintains visibility of regional issues by coordinating with RRTs, states, and regional research groups.

ICCOPR considers the following regional and geographic areas to be of high importance at this time or during the next six-year planning cycle:

The Arctic and Alaska – The extent of sea ice in the Arctic and Alaskan waters has diminished in recent years, a trend that is expected to continue for the foreseeable future. The oil industry is expanding exploration and production operations into the Arctic region as conditions change to make operations feasible in the region. One oil company is drilling in the Arctic Ocean during the 2015 summer season. Understanding and overcoming the operational and logistical challenges of responding to an oil spill in the Arctic region is a major focus of ICCOPR member research planning. This focus is reflected in the number of research priorities (see Chapter 9) that apply directly to Arctic conditions.

Gulf of Mexico – The Gulf of Mexico has abundant oil and gas resources, which results in extensive exploration and production activity. Advances in drilling technology have enabled industry to expand operations into progressively deeper areas of the Gulf. It is also the site of two of the largest oil spills from well blowouts, Macondo/*Deepwater Horizon* and *Ixtoc*, as well as numerous other spills. Federal and state agencies are continuing to conduct studies to determine the short- and long-term effects of the *Deepwater Horizon* oil spill. Both Federal and non-Federal Gulf of Mexico research programs established because of the *Deepwater Horizon* oil spill will continue through the next several years.

Inland Areas – As discussed in Section 1.1, the production of oil and gas from the shale plays in the U.S. and tar sand regions in Canada has dramatically increased over the past five years. The resulting increase in oil shipments by rail and pipeline has elevated the importance of research to prevent and prepare for oil spills from train accidents or pipeline breaks. In addition, the potential for these spills to affect freshwater rivers and lakes necessitates greater emphasis on research into non-marine response techniques.

Atlantic Outer Continental Shelf (OCS) – At present, there are no active oil and gas leases in any of the four Atlantic OCS planning areas. However, the Bureau of Ocean Energy Management (BOEM) Draft Proposed Plan for 2017-2022 proposes one lease sale in the Atlantic in 2021. Preparation for leasing in the Atlantic will involve pre-spill baseline studies to document environmental conditions prior to exploration and drilling.

2. Federal Oil Pollution Research

ICCOPR serves to coordinate research by its member federal agencies and other federal research entities to promote a coordinated approach to addressing oil pollution issues. This section describes ICCOPR and the other federal research entities.

2.1 ICCOPR

2.1.1. Origin

Congress created ICCOPR in the Oil Pollution Act of 1990 (OPA 90). The Committee's membership, roles, and responsibilities are outlined in the original Public Law (P.L.) that mandated its creation, as amended and codified in the United States Code. Consequently, when referencing ICCOPR, it is generally cited with: *Oil Pollution Act of 1990, § 7001, 104 Stat. 484, 559-564 (1990) (33 U.S.C. 2761).*

ICCOPR is charged with two general responsibilities: (1) to prepare a comprehensive, coordinated federal oil pollution research and development plan; and (2) to promote cooperation with industry, universities, research institutions, state governments, and other nations through information sharing, coordinated planning, and joint funding of projects. ICCOPR reports on its activities to Congress every two years.

2.1.2. ICCOPR Membership

ICCOPR is comprised of fifteen federal independent agencies, departments, and department components. The U.S. Coast Guard (USCG) chairs ICCOPR. The National Oceanic and Atmospheric Administration (NOAA), the Bureau of Safety and Environmental Enforcement (BSEE), and the Environmental Protection Agency (EPA) rotate as the vice-chair every two years.

OPA 90 originally stipulated that ICCOPR include representatives from: the Department of Commerce, including NOAA and the National Institute of Standards and Technology (NIST); the Department of Energy (DOE): the Department of the Interior (DOI), including the Minerals Management Service (MMS) and the US Fish and Wildlife Service (USFWS); the Department of Transportation (DOT), including the USCG, the Maritime Administration (MARAD), and the Research and Special Projects Administration (RSPA); the Department of Defense, including the U.S. Army Corps of Engineers (USACE) and the Navy; the EPA; the National Aeronautics and Space Administration; and the US Fire Administration (USFA) in the Federal Emergency Management Agency (FEMA).

Today ICCOPR's original membership remains mostly intact but with some recent changes (Table 2.1). In 2012, the DOI reorganized MMS to form BSEE and the Bureau of Ocean Energy Management (BOEM) – both of which are now members of ICCOPR. Additionally, the USCG and FEMA reorganized under the DHS and DOT re-designated the RSPA as the Pipeline and

Hazardous Materials Safety Administration (PHMSA). In 2013, ICCOPR welcomed its newest member, the U.S. Arctic Research Commission (USARC), to help address emerging issues associated with the Arctic and cold weather environments.

Table 2.1 - ICCOPR Membership

Member	Current Department	Notes
USCG	Homeland Security	Transferred from Transportation
FEMA/USFA	Homeland Security	Originally Independent
MARAD	Transportation	
PHMSA	Transportation	Agency renamed from RSPA
USFWS	Interior	
BSEE	Interior	Formerly part of MMS
BOEM	Interior	Formerly part of MMS
NOAA	Commerce	
NIST	Commerce	
Navy	Defense	
USACE	Defense	
DOE	Energy	
EPA	Independent	
NASA	Independent	
USARC	Independent	Added in 2013

ICCOPR membership may continue to evolve to fully address new research challenges when agency missions change or there are changes in patterns of oil exploration, production, and transportation. OPA 90 provides that the President may designate other agencies as members of ICCOPR. The President delegated this power to the Secretary of the "Department in which the Coast Guard (USCG) operates" through Executive Order 12777 (October 18, 1991) Section 8 (h) and as amended by Executive Order 13286 (March 5, 2003). The Secretary of Homeland Security delegated this power to the USCG Commandant in DHS Delegation No. 0170.1, II.80. ICCOPR may also invite other federal agencies to participate in a non-voting observer role. Currently the U.S. Geological Survey (USGS) is participating in ICCOPR as a non-voting observer.

The diversity of ICCOPR's membership reflects Congress' intent to adequately address the full spectrum of oil spill preparedness, response, and restoration research. Each organization in ICCOPR bears unique regulatory responsibilities, research capabilities, and/or technical expertise that collectively give ICCOPR its knowledge and networks for tackling varying oil pollution research and technology issues. The following sections briefly discuss each of ICCOPR's member organizations and their connections to oil pollution research. Some organizations directly oversee oil pollution research programs while others provide guidance and resource support or specialized expertise.

2.1.2.1 U.S. Coast Guard (USCG)

The USCG serves as the Chair of ICCOPR in accordance with OPA 90. It also serves as the vice-chair of the National Response Team (NRT) and a co-chair of Regional Response Teams (RRTs). The USCG, together with the EPA, has the primary responsibility for federal oil spill response activities. In accordance with the National Contingency Plan (NCP), the USCG is the lead agency for response to spills in the U.S. coastal zone as defined in 40 CFR 300.5.

The USCG provides pre-designated Federal On-Scene Coordinators (FOSCs) for spills in the coastal zone (all United States waters). In addition to spill response, the Coast Guard also has statutory and operational responsibility for oversight of ship design and construction, periodic vessel inspections, investigation of marine casualties, waterway management and port safety and security (including the regulation of hazardous cargoes). These activities all help the USCG improve pollution prevention and response capabilities.

Since 1969, the USCG Research & Development Center (RDC) in New London, Connecticut, has been the Coast Guard's sole facility performing applied oil pollution research, development, test, and evaluation (RDT&E) experimentation and demonstrations.

The USCG also hosts the National Response Center (NRC), which serves as the NRT communications center and the official federal point of contact for pollution incident reports. The National Contingency Plan (40 CFR Part 300) requires that the NRC be notified in the event of an oil spill into navigable water. The U.S. Coast Guard's National Pollution Funds Center (NPFC) administers the Oil Spill Liability Trust Fund (OSLTF) and provides funding from the OSLTF Emergency Fund for responses, compensates claimants for cleanup costs and damages, and takes action to recover costs from responsible parties. The NPFC also provides funding from the OSLTF Principal Fund for operations and for research and development.

2.1.2.2 National Oceanic and Atmospheric Administration (NOAA)

NOAA serves as a rotating Vice Chair of ICCOPR. NOAA provides science, service and stewardship for the oceans and atmosphere; with a goal of healthy ecosystems, communities and economies that are resilient in the face of change. Many components of NOAA may support response to a major oil spill (including the National Ocean Service, National Weather Service;

the National Marine Fisheries Service; the National Environmental Satellite, Data and Information Service; and the Office of Marine and Aviation Operations). A core component of the support is NOAA's Office of Response and Restoration (OR&R) and its network of Scientific Support Coordinators (SSCs) who respond to approximately 120 oil spills annually, primarily in the coastal zone. These SSCs serve as the primary scientific advisors to Federal On-Scene Coordinators (FOSCs), coordinating scientific expertise from federal and State agencies, academia, industry and the local community (40 CFR 300.145). NOAA support includes assessments of hazards, predictions of fate and behavior (trajectories), recommendations on cleanup and mitigation methods and endpoints, emergency consultations on protected resources, environmental information and data management, wildlife operations, meteorological, hydrological and oceanographic observations and forecasts and satellite imagery access and analysis.

NOAA supports the NRT and RRTs as delegated Department of Commerce representatives and serves on workgroups and area committees on activities associated with preparedness, assessment and restoration. NOAA applies and develops tools for emergency response support, transitioning research into operations. In coordination with states and other federal agencies, NOAA produces environmental sensitivity maps, which rank coastal areas by sensitivity to oil and identify priority locations to be protected in a spill. Federal, State and local agencies use these maps to plan and respond to oil spills.

As a Federal Natural Resource Trustee for living marine resources and their habitat, NOAA is required to assess the injuries that result from an oil spill, to determine and recover monetary compensation and, using those sums, to restore, rehabilitate or recover the equivalent of the damaged resources. NOAA is also responsible for the issuance and implementation of regulations governing oil spill damage assessment.

2.1.2.3 National Institute of Standards and Technology (NIST)

Founded in 1901, NIST is a non-regulatory federal agency within the U.S. Department of Commerce. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. NIST has a long history of scientific, technical and measurement support to other federal agencies and U.S. industry on a reimbursable basis.

NIST maintains unique measurement facilities and has an experienced technical staff able to assist with oil spill response and oil pollution research providing a wide variety of scientific and measurement services. NIST's most recent activities relating to oil spills include developing protocols for sampling of protected species, providing for archival for marine animal specimens associated with oil spills, conducting interlaboratory comparison exercises for laboratories involved in assessing oil contamination, providing measurements of contamination in archived marine mammals and seabirds, and assisting with measuring oil flow from well blow-outs. NIST develops Standard Reference Materials (SRMs) for crude oil and other fossil-fuel materials and additionally has groups involved with research in Fire and Pipeline Safety. NIST maintains and manages the Marine Environmental Specimen Bank (ESB) that contains marine mammal samples dating back as far as the Exxon Valdez oil spill damage assessment and includes marine organism samples from the Pacific Islands, Alaska, and coastal regions of the lower 48 states. NIST has worked more than 30 years developing environmental specimen banking technology so that samples can be used to understand environmental exposure and effects from oil and other contaminants. Because samples have been collected continuously from many locations they provide a resource in the event of a spill to establish pre-spill baseline conditions.

2.1.2.4 U.S. Department of Energy (DOE)

The DOE works to ensure America's energy security and prosperity by addressing energy and environmental challenges with research and technology solutions. This includes ensuring the prudent development of America's oil and natural gas resources through R&D that improves the safety and environmental performance of oil and natural gas exploration and production.

In its offshore research program, DOE works toward mitigating the risks and challenges associated with drilling and production operations through a research portfolio dedicated to oil spill prevention. Completed and ongoing research focus on the following areas: geologic uncertainty; drilling and completions; surface systems and umbilicals; and subsea systems reliability/automated safety systems.

Onshore DOE focuses on prudent development of unconventional oil and gas resources with emphasis on resource characterization, protecting water quality, increasing water availability, protecting air quality, and reducing induced seismicity associated with waste water injection. The advent of shale gas development also brings a host of safety and environmental issues, including: 1) demand for water for use in hydraulic fracturing; 2) protection of drinking water aquifers; 3) evaluation of the safety of chemicals used in fracturing; 4) environmental impacts resulting from the treatment and/or disposal of produced or fracturing flowback water; 5) air quality impacts; and 6) community safety issues.

DOE's National Energy Technology Laboratory (NETL) conducts laboratory, field, and modeling-based research on offshore oil spill prevention, focusing on reducing the risk and mitigating the risk of a loss of well control that leads to spills. Onshore modeling includes life cycle analysis of natural gas, and modeling of methane emissions.

2.1.2.5 Bureau of Safety and Environmental Enforcement (BSEE)

The DOI's BSEE serves as a rotating Vice Chair of ICCOPR. The Bureau works to promote safety, protect the environment, and conserve energy resources offshore through vigorous regulatory oversight and enforcement. The BSEE develops standards and regulations to enhance operational safety and environmental protection in connection with the exploration and development of offshore oil, natural gas, and renewable energy sources on the U.S. Outer

Continental Shelf (OCS); and undertakes actions to ensure compliance with those standards and regulations. BSEE has two research programs that support its mission. The Technology Assessment Program supports research regarding operational safety and pollution prevention related to offshore oil and natural gas and renewable energy exploration and development. The Oil Spill Response Research Program is dedicated to improving oil spill response options. The major focus of the program is to support BSEE's mission of ensuring offshore operators are prepared to respond to any potential oil spill. Research is conducted to improve the methods and technologies used for oil spill detection, containment, treatment, recovery and cleanup.

As part of ensuring that offshore operators are prepared to respond to an oil spill BSEE conducts oil spill response plan reviews, government-initiated unannounced exercises, equipment inspections, and audits of oil spill removal organizations and spill management training. Risks identified through these activities are mitigated by directed changes to plans, training programs, equipment, response strategies, and BSEE-funded research projects.

The BSEE also manages the operation of the national Oil Spill Response Research & Renewable Energy Test Facility (Ohmsett), the only facility where full-scale oil spill response equipment testing, research, and training can be conducted in a marine environment with oil under controlled environmental conditions (waves and oil types). OPA 90 mandated continued operation of Ohmsett. (See Section 2.3.1.)

2.1.2.6 Bureau of Ocean Energy Management (BOEM)

The DOI's BOEM manages the exploration and development of the nation's offshore resources on the U.S. Outer Continental Shelf (OCS). It seeks to appropriately balance economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies. BOEM conducts studies to improve pre-spill baseline information and estimates of oil-spill transport, fate, and impacts to the environment. BOEM manages an Environmental Studies Program (ESP), which, since 1973, has included: development and use of oil transport and weathering models; measurement of oil effects in laboratory and field conditions on marine organisms including birds, fish, and mammals; identification of sensitive biological resources; and assessment of the social and economic impacts of oil development. While some of the ESP consists of in-house investigations, BOEM manages a substantially larger program that is conducted by contractors, industry, universities, and other federal agencies. Interagency coordination of this program is overseen by the National Ocean Pollution Policy Board and the Interagency Arctic Research Policy Committee, in addition to review provided by the OCS Scientific Committee.

2.1.2.7 U.S. Fish and Wildlife Service (USFWS)

The DOI's USFWS has trustee responsibility for migratory birds, threatened and endangered species, certain marine mammals, anadromous and catadromous fish, and national wildlife refuge lands. The USFWS is the primary DOI Bureau that responds to oil spills, provides information and advice on safeguarding sensitive habitats and protected species (including advice on use of dispersants and other chemicals), and oversees the rescue and the rehabilitation of oiled birds and certain marine mammals. It works closely with state fish and wildlife agencies to ensure the protection of potentially affected fish and wildlife and takes an active role in protecting USFWS lands, such as national wildlife refuges. USFWS, in its role as trustee, is also the most active DOI bureau in natural resource damage assessment and restorations (NRDAR). In addition to civil actions, USFWS may also pursue criminal violations of the Migratory Bird Treaty Act, Marine Mammal Protection Act, and the Endangered Species Act.

The USFWS R&D efforts are focused on identifying chemical pollutants and their metabolites in biological tissues; defining and mapping wetlands, other critical habitats and natural resources; inventorying species of particular concern, including threatened and endangered species; developing biological indicators and economic tools for damage assessment; and determining biological requirements for sustaining viable populations and habitats and identifying factors contributing to their demise. The USFWS R&D efforts support the needs of the DOI in meeting the operational needs and the requirements of OPA 90.

2.1.2.8 Maritime Administration (MARAD)

The DOT's MARAD is tasked with promoting the use of waterborne transportation and its seamless integration with other segments of the transportation system, and the viability of the U.S. merchant marine. MARAD's role in maritime transportation spans many areas involving ships and shipping, shipbuilding, port operations, vessel operations, national security, environment, and safety. MARAD supports the Maritime Environmental and Technical Assistance (META) program, which focuses on environmental research and demonstration projects. The Maritime Administration collaborates extensively with stakeholders from all transportation sectors and modes in order to accomplish its mission to improve and strengthen the U.S. marine transportation system. Through long range planning and analysis, the Maritime Administration's Office of Policy and Plans looks ahead and develops plans for integrating the Maritime Administration's activities with those of other appropriate government agencies, as well as private sector marine transportation stakeholders.

2.1.2.9 Pipeline & Hazardous Materials Safety Administration (PHMSA)

The mission of DOT's PHMSA is to protect people and the environment from the risks of hazardous materials transportation by establishing national policy, setting and enforcing standards, providing education, and conducting research to prevent oil spills and hazardous materials incidents. PHMSA's Office of Pipeline Safety promulgates and enforces regulations addressing the design, construction, operation and maintenance of pipeline systems. PHMSA's Pipeline Safety Research Program supports the PHMSA mission by: 1) funding technology development research; and 2) generating and sharing new technical knowledge with decision makers in support of planning, evaluating, and implementing pipeline safety programs. This research focus is providing near-term solutions that will increase the safety, reduce environmental impact and improve reliability of the Nation's pipeline system.

PHMSA, via its Office of Hazardous Materials Safety, also provides support to federal agencies in oil spill related areas such as logistics management, transportation infrastructure, telecommunications, command and control systems, expert computer systems, facilities maintenance management, mobilization preparedness and hazardous materials transportation by any mode.

2.1.2.10 US Army Corps of Engineers (USACE)

The USACE has specialized equipment and personnel that can be used in oil spill response activities. The Corps has responsibilities for maintaining navigation channels, removing obstructions, performing structural repairs, and maintaining hydropower electric generating equipment. Their Engineer Research and Development Center (ERDC) conducts research and development (R&D) in support of the Soldier, military installations and civil works projects (water resources, environmental missions, etc.) as well as for other federal agencies, state and municipal authorities, and with U.S. industry through innovative work agreements. USACE ERDC has seven laboratories in four states: Construction and Engineering Research laboratory in Champaign, Illinois; Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire; Geospatial Research Laboratory in Alexandria, Virginia; and the Coastal and Hydraulics, Geotechnical and Structures, Environmental, and Information Technology Laboratories in Vicksburg, Mississippi. CRREL, maintains unique cold facilities to conduct research on oil spill detection and response in Arctic and other ice covered waters. Other USACE research with applicability to oil pollution issues include providing technical support on wind and wave effects, diffusion, remote sensing, satellite imaging, image enhancement systems, alternative methods for removing oil, shoreline cleanup and environmental evaluation, effects and mitigation.

The Corps also assists in design and construction and, on a reimbursable basis, provides technical manpower and support for any federal agency involved in any aspect of research and development described in this Plan. Special note should be made of USACE capabilities for assisting in the engineering aspects of conducting various research projects. As the nation's environmental engineer, the USACE manages one of the largest federal environmental missions: restoring degraded ecosystems; constructing sustainable facilities; regulating waterways; managing natural resources; and cleaning up contaminated sites from past military activities.

2.1.2.11 U.S. Navy (USN)

NAVSEA's Directorate of Ocean Engineering, Supervisor of Salvage and Diving (SUPSALV) experts provided technical, operational, and emergency capabilities in marine salvage, pollution abatement, diving, diving system certification, and underwater ship husbandry to improve Fleet readiness and capability across the globe. SUPSALV has been the Navy's oil pollution experts since the 1970s, as required by the Federal Water Pollution Control Act. The USN has expertise in preventing and responding to oil spills from ships. Upon the request of an On-Scene Coordinator, the USN may provide technical assistance in the ocean engineering disciplines of marine salvage, shipboard damage control, pollution abatement, diving, diving system certification, and underwater ship husbandry. The USN also owns specialized containment, collection, and removal equipment designed for salvage-related and near shore to open-sea pollution incidents. The equipment design and systems make it transportable and sustainable in the field. The USN has successfully deployed and operated its equipment at almost every major oil spill in the past 35 years.

2.1.2.12 U.S. Fire Administration (USFA)

As an entity of FEMA, USFA provides national leadership to foster a solid foundation for fire and emergency services stakeholders in prevention, preparedness, and response. The Agency was established by Public Law 93-498, the Federal Fire Prevention and Control Act of 1974, which called for: 1) the establishment of a National Fire Academy to advance the professional development of the fire service personnel and of other persons engaged in fire prevention and control activities; 2) a technology program of development, testing, and evaluation of equipment for use by the Nation's fire, rescue, and civil defense services; and 3) the operation of a National Fire Data Center for the selection, analysis, publication, and dissemination of information related to the prevention, occurrence, control and results of fires of all types; and ; 4) education of the public to overcome public indifference toward fire and fire prevention. USFA focuses on supplementing, not duplicating, existing programs of training, technology and research, data collection and analysis, and public education. While USFA does not directly conduct oil spill pollution research, it provides valuable emergency service expertise and connectivity to a number of emergency management programs.

2.1.2.13 U.S. Environmental Protection Agency (EPA)

The EPA serves as the Chair of the National Response Team (NRT), as co-chair of all the Regional Response Teams (RRTs), and as a rotating Vice Chair for ICCOPR. EPA works closely with the USCG in coastal spill response activities. In accordance with the National Contingency Plan (NCP), the EPA is the lead agency for response to spills in the U.S. inland zone. The EPA provides pre-designated On-Scene Coordinators (OSCs) for the inland zone, and maintains assets that can be used for command, control, and surveillance of oil spills. EPA also provides legal expertise on the interpretation of applicable environmental statutes.

The EPA issues and implements federal regulations regarding oil spills under the Clean Water Act, including the NCP. It implements spill prevention regulations for non-transportation-related facilities. Also, through Subpart J of the NCP, EPA maintains a Product Schedule of dispersants and other oil spill mitigating substances and regulates their use during spill response.

The EPA provides expertise on cleanup technologies and the environmental effects of oil spills. Its Environmental Response Team (ERT) is a group of highly trained scientists and engineers whose capabilities include multimedia sampling and analysis, hazard evaluation, contamination monitoring, cleanup techniques, and overall technical support to the OSCs. The EPA's R&D activities include the development of test protocols to evaluate the efficacy and toxicity of spill mitigating agents (e.g., dispersants), and research to determine the fate and effects of oil following a spill.

2.1.2.14 National Aeronautics and Space Administration (NASA)

NASA develops and maintains several technologically advanced airborne and satellite systems suitable for spill observation and mapping. The agency's multi-disciplinary team of scientists, engineers and computer modelers also analyzes vast archives of data for insights into Earth's interconnected systems -- atmosphere, ocean, ice, land, and biosphere; and openly provides that data to the global community. They design and deploy airborne, ground-based and ocean-going field campaigns to study the earth from the heights of the stratosphere to the depths of the ocean to the remote ice caps at the poles. NASA also works with other government agencies and partner organizations to apply NASA data and computer models to improve decision-making and problem solving.

2.1.2.15 U.S. Arctic Research Commission (USARC)

The USARC is an independent federal agency created by the Arctic Research and Policy Act of 1984, as amended. It consists of a nonpartisan advisory body of scientists, physicians, indigenous leaders, and industry representatives appointed by the President of the U.S. and supported by staff located in Washington, D.C. and Anchorage, AK. The Commission sets U.S. Arctic research policy and builds cooperative links in Arctic research including: 1) the U.S. Arctic research program; 2) to international research partners, and; 3) Alaska. The law requires the Commission to comment to Congress on the progress of the executive branch in reaching goals set by the Commission and on their adoption by the Interagency Arctic Research and Policy Committee. The Commission plays an active role in the work of several interagency committees, including the Arctic Policy Group, chaired by the U.S. Department of State, which oversees U.S. participation in the eight-nation Arctic Council. The Commission is a statutory member of: the North Pacific Research Board and the North Slope Science Initiative. USARC is also a member of: various committees of the National Ocean Governance Structure; the interagency Extended Continental Shelf Task Force; the Scientific Ice Expeditions Interagency Committee, involving U.S. Navy nuclear submarines in the Arctic; the Alaska Ocean Observing System; the International Permafrost Association; and the Consortium for Ocean Leadership.

2.2. Other Federal Stakeholders and Entities

Several Federal stakeholders and organizations also conduct research or affect oil pollution research. These include Federal independent organizations (i.e., committees, councils), agencies not currently members of ICCOPR, and ICCOPR member components that do not actively participate within ICCOPR. Other entities set Federal policies that guide or focus research initiatives on specific topics. ICCOPR maintains awareness of these stakeholders and works with them to coordinate research efforts.

2.2.1 Arctic Executive Steering Committee (AESC)

The AESC was formed in 2015 by Executive Order to provide guidance to executive departments and agencies (agencies) and enhance coordination of Federal Arctic policies across agencies and offices, and, where applicable, with State, local, and Alaska Native tribal governments and similar Alaska Native organizations, academic and research institutions, and the private and nonprofit sectors. The AESC provides guidance and coordinate efforts to implement the priorities, objectives, activities, and responsibilities identified in National Security Presidential Directive 66/Homeland Security Presidential Directive 25, Arctic Region Policy, the National Strategy for the Arctic Region (NSAR), the NSAR Implementation Plan (NSAR-IP), and related agency plans. The AESC does not conduct oil pollution research but can influence the policies guiding research in the Arctic.

2.2.2 Federal Oil Spill Team for Emergency Response Remote Sensing (FOSTERRS)

The Federal Oil Spill Team for Emergency Response Remote Sensing (FOSTERRS) is an interagency working group organized in 2015 to facilitate the sharing of remote sensing capabilities and to discuss improvements in disaster response using remote sensing. Specifically, FOSTERRS seeks to connect agency information on airborne and space borne asset's availability, limitations, capabilities and performance, and ancillary data needs to stake holders and responders. FOSTERRS includes members from agencies (NOAA, NASA, and USGS) with remote sensing assets and key end users. It also reaches out to the larger community involved in marine disaster response and the development and implementation of remote sensing best practices.

2.2.3 Federal Rail Administration (FRA)

The Department of Transportation Act of 1966 created the FRA with a mission to enable the safe, reliable, and efficient movement of people and goods for a strong America, now and in the future. It is one of ten agencies within the DOT concerned with intermodal transportation.

FRA's Office of Railroad Safety promotes and regulates safety throughout the Nation's railroad industry. The office executes its regulatory and inspection responsibilities through a diverse staff of railroad safety experts who are responsible for five safety disciplines focusing on compliance and enforcement in:

- Hazardous Materials;
- Motive Power and Equipment;
- Operating Practices;
- Signal and Train Control; and
- Track.

2.2.4 U.S. Geologic Survey (USGS)

The USGS supports an array of scientific capabilities and assets that address many elements of oil pollution research. As a science agency for DOI, the USGS provides science leadership and collaborations with other federal agencies during oil spill response. USGS research capabilities related to oil pollution include the development of objective and reliable scientific information needed to inform policies and practices that help avoid exposure to toxic substances, mitigate environmental deterioration from contaminants, provide cost-effective cleanup and waste-disposal strategies, and reduce future risk of contamination. USGS science primarily focuses on inland area but also includes near-shore and off-shore environments.

USGS oil pollution related capabilities include long-term monitoring of the Exxon Valdez, Deepwater Horizon, and inland oil spills. Also, the USGS Patuxent Wildlife Research Center has been studying the effects of crude oil and petroleum products on birds since the late 1970's. The USGS Coastal and Marine Program develops 3-D hydrodynamic models that can predict the nearshore sources, transport, and fate of oil. The USGS Energy Program provides capabilities to characterize chemical fingerprints of oil to identify sources of tar balls and support post-spill shoreline assessments.

2.2.5 Gulf Coast Ecosystem Restoration Council

The RESTORE Act established a Gulf Coast Ecosystem Restoration Council (the Council), which is comprised of governors from the five affected Gulf States, the Secretaries from the U.S. Departments of the Interior, Commerce, Agriculture, and Homeland Security as well as the Secretary of the Army and the Administrator of the U.S. Environmental Protection Agency. The Gulf States recommended and President Obama appointed the Secretary of Commerce as the Council's Chair.

2.2.6 Gulf of Mexico Fishery Management Council (GMFMC)

The GMFMC is one of eight regional Fishery Management Councils established by the Fishery Conservation and Management Act of 1976. The Council prepares fishery management plans designed to manage fishery resources from where state waters end, out to the 200-mile limit of the Gulf of Mexico. These waters are also known as the Exclusive Economic Zone (EEZ). The

Council consists of voting members from the NMFS, the five Gulf state marine resource management agencies, and nominees by the State governors. In addition, there are four nonvoting members representing the USCG, U.S. Fish and Wildlife Service, Department of State, and the Gulf States Marine Fisheries Commission. The GMFMC provides an advisory role in directing scientists on where to focus their research. Current priorities include research on species recovering from the Deepwater Horizon oil spill and broad research on long-term fisheries data.

2.2.7 U.S. Marine Mammal Commission (MMC)

The MMC is an independent agency of the U.S. government established under Title II of the Marine Mammal Protection Act (MMPA). The Commission provides independent oversight of the marine mammal conservation policies and programs of federal agencies. The Commission's main roles with respect to oil spills are oversight of the agencies charged with response, assessment, and restoration activities, and convening of interagency working groups to coordinate those activities.

The Commission, in consultation with its Committee of Scientific Advisors on Marine Mammals, has prepared a report "Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in the Gulf of Mexico: A Statement of Research Needs" (2011). The objectives of the report were to (1) guide assessment of the long-term effects of the Gulf spill and associated risk factors on marine mammals, (2) guide mitigation and restoration efforts for Gulf marine mammal populations, (3) help track the changes in the Gulf ecosystem, including recovery and restoration, and (4) help guide assessment of future spills in the Gulf and elsewhere.

The Commission administers a small annual grant program that supports projects aimed at meeting the conservation and protection goals of the MMPA. In addition, the Commission has initiated an annual survey of federally funded research on marine mammals to determine the nature of research conducted or supported by each agency. Information from the survey is used to assess ways to target and enhance specific marine mammal research and conservation activities.

2.2.8 National Institute of Environmental Health Sciences (NIEHS)

NIEHS is one of 27 research institutes and centers that comprise the National Institutes of Health (NIH) of the Department of Health and Human Services (DHHS). The mission of the NIEHS is to reduce the burden of human illness and disability by understanding how the environment influences the development and progression of human disease. The NIEHS, part of the NIH, activated programs throughout the institute to provide timely and responsive services following the DWH oil spill.

In June 2010, NIEHS initiated the GuLF STUDY to conduct research on the health of the workers and volunteers most directly involved in responding to the Deepwater Horizon oil spill.

The GuLF STUDY will help determine if oil spills and the exposure to crude oil and dispersants, affects physical and mental health. Almost 33,000 cleanup workers are enrolled in the 10-year health study, making a significant contribution to their communities and to answering important public health questions.

2.2.9 U.S. National Response Team (NRT) - Science and Technology (S&T) Committee

The NRT is an organization of 15 federal departments and agencies responsible for coordinating emergency preparedness and response to oil and hazardous substance pollution incidents. The EPA and the USCG serve as Chair and Vice Chair respectively. The NCP and the Code of Federal Regulations (40 CFR part 300) outline the role of the NRT and Regional Response Teams (RRTs). Various federal statutes cite the NRT and RRTs including the Superfund Amendments and Reauthorization Act - Title III and the Hazardous Materials Transportation Act (HMTA).

The NRT's S&T Committee provides a forum to fulfill the NRT's NCP delegated responsibilities in R&D. Specifically, NCP regulation 40 CFR 300.110(h)(6) lists as one of the NRT's responsibilities "Monitoring response-related research and development, testing, and evaluation activities of NRT agencies to enhance coordination, avoid duplication of effort, and facilitate research in support of response activities." Additionally, 40 CFR 300.110(g) states, "the NRT may consider and make recommendations to appropriate agencies on ... necessary research, development, demonstration, and evaluation to improve response capabilities."

2.2.10 National Science Foundation (NSF)

The NSF is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" The NSF is the funding source for approximately 24 percent of all federally supported basic research conducted by America's colleges and universities. NSF fulfills their mission chiefly by issuing limited-term grants to fund specific research proposals judged to be the most promising by a rigorous and objective merit-review system. Currently, they issue about 11,000 new awards per year, with an average duration of three years. NSF-funded research addresses a number of scientific areas with applications to oil pollution research including engineering, materials science, biology, and the Arctic. NSF also has a Rapid Response Research (RAPID) mechanism that enables research on unanticipated events such as the *Deepwater Horizon* oil spill.

2.2.11 NOAA RESTORE Act Science Program

In 2012, the U.S. Congress passed (P.L. 112-141) the "Resources and Ecosystem Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act" (RESTORE Act). The RESTORE Act transfers 80% of all administrative and civil penalties paid by responsible parties in connection with the Deepwater Horizon incident to a Gulf Coast Restoration Trust

Fund. The RESTORE Act also establishes several programs, funded by the Trust Fund, to aid in the ecological and economic recovery of the Gulf Coast states. Under Section 1604 of the RESTORE Act directed NOAA to establish a Gulf Coast Ecosystem Restoration Science, Observation, Monitoring, and Technology Program (NOAA RESTORE Act Science Program). This program is to be funded by 2.5 percent of the Gulf Coast Ecosystem Restoration Trust Fund plus 25 percent of the Trust Fund accrued interest. The Program can expend funds for marine and estuarine research; marine and estuarine ecosystem monitoring and ocean observation; data collection and stock assessments; pilot programs for fishery independent data and reduction of exploitation of spawning aggregations; and cooperative research.

2.2.12 North American Wetlands Conservation Act (NAWCA) Gulf of Mexico Funds

The NAWCA provides matching grants from the North American Wetlands Conservation Fund to organizations and individuals who have developed partnerships to carry out wetlands conservation projects in the United States, Canada, and Mexico for the benefit of wetlands-associated migratory birds and other wildlife. As part of their criminal settlement agreement, BP paid $100 million to the Fund for the purpose of wetlands restoration and conservation located in states bordering the Gulf of Mexico or otherwise designed to benefit migratory bird species and other wildlife affected by the Macondo oil spill. The USFWS administers the Fund. The restoration projects include research to monitor and evaluate restoration success.

2.3 Federal Research Laboratories and Testing Facilities

Several federal facilities and locations provide opportunities for both federal and non-federal oil pollution research.

2.3.1 Ohmsett

Ohmsett, located at the Naval Weapons Station Earle Waterfront in Leonardo, New Jersey, is managed by BSEE. The facility includes an above ground concrete test tank that is one of the largest of its kind, measuring 203 meters long by 20 meters wide by 3.4 meters deep. The tank holds with 2.6 million gallons of crystal clear saltwater.

The Ohmsett test tank allows testing of full-scale oil pollution response equipment. The tank includes a wave generator that creates realistic sea environments, while state-of-the-art data collection and video systems record test results. The facility has proven to be ideal for testing equipment, evaluating acquisition options, and validating research findings.

Government agencies, academia, public and private companies use Ohmsett as a research center to test oil spill containment/clean-up equipment and techniques, to test new designs in response equipment, and to conduct training with actual oil spill response technologies.

2.3.2 USCG Research & Development Center (RDC)

The RDC, located in New London, Conn. is the USCG's sole facility performing research, development, and test and evaluation in support of the service's major missions. The RDC is responsible for evaluating the feasibility and affordability of mission execution solutions and providing operational and risk-management analysis at all stages of the acquisition process.

At any given time, the RDT&E program is working on more than 80 projects that support USCG requirements across all mission areas. The program also provides Coast Guard leadership with knowledge necessary for making strategic decisions. The RDT&E program leverages partnerships with academia and other government agencies. The RDC also leverages Cooperative Research and Development Agreements (CRADAs) under the Technology Transfer Act to work with private industry to anticipate and research solutions to current and future technological challenges.

2.3.3 USCG RDC Joint Maritime Test Facility

The USCG RDC's Joint Maritime Test Facility *In Situ* Burn Pan is working in conjunction with the Naval Research Laboratory and the BSEE to refurbish its *in-situ* burn test pan located on Little Sand Island in Mobile, Alabama. The burn pan is the nation's only permitted open air *in-situ* burn pan for fire boom research. Once refurbished, this burn pan will help the RDC's Joint Maritime Test Facility meet its mission to support the maritime safety efforts by providing full-scale tests and evaluation under close to actual operating and environmental conditions.

2.3.4 USCG Marine Safety Laboratory

The USCG Marine Safety Laboratory (MSL) provides forensic oil analysis and expert testimony in support of the oil pollution law enforcement efforts for Marine Investigators, Districts, Hearing Officers, National Pollution Funds Center, Department of Justice, and other federal agencies. The MSL is the USCG's sole facility for performing forensic oil analysis.

2.3.5 U.S. EPA National Risk Management Research Laboratory (NRMRL)

The NRMRL is EPA's premiere laboratory for risk management research. It conducts research at the basic level, as well as bench-scale and pilot-scale levels, to explore innovative solutions to pollution problems. Environmental risk management seeks to determine what environmental risks exist and how to manage those risk in a way best suited to protect human health and the environment. Its mission is to advance scientific and engineering solutions to manage current and future environmental risk.

NRMRL's research directly supports efforts to manage chemical risks, clean up hazardous waste sites, protect water, reduce greenhouse gas emissions, and improve air quality.

2.3.6 Cold Regions Research and Engineering Laboratory (CRREL)

CRREL, located in Hanover, New Hampshire is one of seven US Army Corps of Engineers (USACE) Engineering Research and Development Center (ERDC) laboratories. The laboratory's mission is to solve interdisciplinary and strategically important problems by advancing and applying science and engineering to complex environments, materials and processes in all seasons and climates, with unique core competencies related to the Earth's cold regions. CRREL maintains several unique and specialized research facilities at its Hanover, New Hampshire location, to include: 26 low-temperature research cold rooms; a refrigerated Ice Engineering Facility comprised of a 12,800 square foot research area, a 3,600 square foot by 8 foot deep test basin, and a 120 foot long water flume with tilting bed; a 1,320 square foot by 7 foot deep outdoor Geophysical Research Facility; a 40 foot working length portable wave tank that can be located indoors within a cold facility for year round cold research or outdoors to support in situ burn tests; and a 29,000 square foot environmentally controlled Frost Effects Research Facility. CRREL also maintains a research permafrost tunnel in Fox, Alaska, a 135-acre permafrost research site near Fairbanks, Alaska, and has project offices in Anchorage and Fairbanks, Alaska. CRREL works with partners from industry, government agencies, and educational institutions, to develop scientific tools that can aid in effective oil spill response, and provides unique facilities and cold region expertise to stake-holders to create effective spill response techniques for ice covered environments.

2.3.7 U.S. Army Engineer Research and Development Center (ERDC)

The ERDC is the world's largest laboratory primarily devoted to civil engineering and environmental sciences research, development, test, and evaluation. The ERDC, which includes seven laboratories located in four geographic locations, provides a broad array of services ranging from basic research to test and evaluation. The ERDC Laboratories maintain state of the art modeling and experimentation facilities which support a broad array of capabilities in oil spill response from modeling impacts to remediation techniques.

ERDC capabilities to support Oil Spill efforts are categorized into three phases. Phase 1, Emergency Response/Mitigation, includes those activities that that enhance the ability to conduct emergency response and mitigation. Phase 2, Remediation, includes activities designed to support tasks such as active intervention to ameliorate the oil contamination. Phase 3, Recovery/Long Term Monitoring/Assessment, includes activities supporting the monitoring and assessment of long term environmental impacts associate with the spill.

2.3.8 Hollings Marine Laboratory (HML)

The Hollings Marine Laboratory is located in Charleston, SC and was established as a joint facility combining partners from NOAA, NIST, the Medical University of South Carolina, the College of Charleston, and the South Carolina Department of Natural Resources. The laboratory is operated by the NOAA National Ocean Service and houses NIST's Environmental Specimen

Bank, NIST and NOAA environmental chemistry laboratories, as well as NOAA personnel and facilities for assessing the health of living marine resources. Immediately after the Deepwater Horizon oil spill, the co-location of NOAA and NIST personnel was instrumental in planning and mounting NOAA's response to the event with regard to, sample archival, monitoring protected species and evaluating data quality being produced by different laboratories providing chemistry data related to the spill. Oil spill-related research continues at the HML with projects including aiming to understand biomarkers of oil exposure in protected species and exploring the effects of dispersants on marine organisms and humans.

2.2.9 U.S. Naval Research Laboratory (NRL) Stennis Space Center

The NRL detachment at Stennis Space Center focuses on marine geosciences, oceanography, and underwater acoustics. The Oceanography Division and the Marine Geosciences Division conduct studies applicable to oil pollution research.

The Oceanography Division is known for its combination of theoretical, numerical, and experimental approaches to oceanographic problems. The Division numerically models the ocean on the world's most powerful supercomputers and operates a number of highly sophisticated graphics systems to visualize ocean model results. The Division maintains two satellite receiving systems, a computer network with automated processing capabilities for ocean color and advanced optical instrumentation and calibration facilities.

The Marine Geosciences Division conducts a broadly-based, multidisciplinary program of scientific research and advanced technology development directed towards maritime and other national applications of geosciences, geospatial information and related technologies. Research includes investigations of basic processes within ocean basins and littoral regions. The Division develops models, sensors, techniques and systems to exploit this knowledge for applications to enhance Navy and Marine Corps systems, plans and operations

2.3.10 Pacific Northwest National Laboratory (PNNL)

The PNNL's Marine Sciences Laboratory (MSL), located in Sequim, Washington on the Strait of Juan de Fuca, provides a platform for marine and freshwater ecological research, instrument and method development, and biotechnology research. The laboratory has regional access to oceans and rivers that have experienced human impacts ranging from the uninhabited and protected coastlines of Olympic National Park to heavily developed shores around Seattle and Tacoma. The Marine Research Operations' Wet Laboratory provides a large space in which to perform innovative, water-oriented research. A variety of indoor and outdoor tank configurations provide capacity for bench-scale tests through large-scale outdoor mesocosm systems and for other studies using aquatic plants and animals.

2.3.11 Coastal and Ocean Research Vessels

2.3.10.1 USCG Cutter Healy

The USCG's cutter *Healy* is designed to conduct a wide range of research activities, providing more than 4,200 square feet of scientific laboratory space, numerous electronic sensor systems, and accommodations for up to 50 scientists. HEALY is designed to break 4½ feet of ice continuously at three knots and can operate in temperatures as low as -50 °F. *Healy* substantially enhances the U.S. Arctic research capability. It serves as a platform for research activities as part of the Arctic Shield demonstrations where components of an Arctic oil spill response are tested. *Healy* is also a capable platform for supporting other potential missions in the polar regions, including logistics, search and rescue, ship escort, environmental protection, and enforcement of laws and treaties.

2.3.11.2 EPA Vessels

The EPA operates two ships that monitor and assess impacts from ecological disturbances and ocean-based human activities on the ocean, Great Lakes, and coastal waters. EPA's Ocean Survey Vessel (OSV) *Bold* operates under the statutory requirement to monitor the deposition of dredged materials under the Marine Protection, Research, and Sanctuaries Act of 1972. This Act regulates intentional ocean disposal of materials, authorizes any related research and provides for the designation and regulation of marine sanctuaries. OSV *Bold* operates in the Atlantic and Pacific Oceans and the Caribbean Sea to monitor water quality, effects of dredged material, coral reef health, and other special assessments.

EPA's Great Lakes National Program Office based in Chicago, Illinois operates R/V *Lake Guardian*, which conducts monitoring programs that sample the water, aquatic life, sediments, and air in order to assess the health of the Great Lakes ecosystem.

2.3.11.3 MARAD Vessels

MARAD operates the National Defense Reserve Fleet (NDRF) of 100 ships that are available for use during oil spill exercises, providing housing during a spill response, or for education and training. The NDRF is available to support emergency shipping operations during war and national emergencies. The fleet has anchorages in Fort Eustis, Virginia; Beaumont, Texas; Suisun Bay in Benicia, California; and at designated port facility berths.

2.3.11.4 NOAA Vessels

NOAA's Office of Marine and Aviation Operations (OMAO) operates a wide assortment of hydrographic survey, oceanographic research, and fisheries survey vessels. Five ships located in the Pacific are managed by the Marine Operations Center, Pacific (MOC-P) in Newport, Oregon. Nine ships located in the Atlantic are managed by the Marine Operations Center, Atlantic (MOC-A) in Norfolk, Virginia. Two ships located in Hawaii are managed by the Marine Operations Center, Pacific Islands (MOC-PI).

NOAA's research and survey ships compose the largest fleet of federal research ships in the nation. The fleet ranges from large oceanographic research vessels capable of exploring the world's deepest ocean, to smaller ships responsible for charting the shallow bays and inlets of the United States. The fleet supports a wide range of marine activities including fisheries research, nautical charting, and ocean and climate studies.

The OMAO's aircrafts operate throughout the world providing a wide range of capabilities including hurricane reconnaissance and research, marine mammal and fisheries assessment, and coastal mapping.

2.3.12 Oil Spill Field Research

Federal oil pollution research is not limited to research facilities and laboratories. Oil spills can provide opportunities for federal agencies to conduct research on the fate, effects, and physical and chemical behavior of the spilled oil and the responses to the spills in the natural environment. NOAA and USGS have ongoing research projects to study the long-term fate and effects of the *Exxon Valdez* oil spill. The *Deepwater Horizon* oil spill is also providing many opportunities to study both the near-term and long-term effects of the spill and response. Other potential research locations include the Santa Barbara oil seeps off the California coast and the submerged Taylor Energy platform in the Gulf of Mexico, which is a continuing source of sheens.

Intentional releases have been used by many countries, most notably Norway, to demonstrate the effectiveness of spill control equipment or processes. Under controlled circumstances, these releases may provide an opportunity to conduct tests under actual spill conditions.

3. Non-Federal Oil Pollution Research Entities

Consistent with the mandates of OPA 90, ICCOPR cooperates with research programs of state governments, industry, academia, non-government organizations/institutions, and other nations. The cooperation of federal and non-federal entities provides whole community approach to oil pollution research. The following sections describe non-federal entities that conduct or sponsor oil pollution research.

3.1 State Organizations

Several coastal states have established oil pollution research programs. These programs are in states affected by previous oil spills or where there are active oil exploration and production activities. Increasing shale oil production has prompted other states to study the risks of hydraulic fracturing and transporting oil by rail and pipeline. This section describes on-going state research programs.

3.1.1 Alaska Department of Environmental Conservation (ADEC)

Judgments entered in the criminal cases for the *Exxon Valdez* oil spill resulted in appropriation of funds to the State of Alaska to enhance the ability of the State and industry to respond to oil spills. A total of $2,500,000 was made available to ADEC for projects under this program. The funds are used for research programs directed toward the prevention, containment, cleanup and amelioration of oil spills in Alaska. In cooperation with other stakeholders, ADEC has developed a list of more than 30 R&D projects dealing with such subjects as cleanup technology, non-mechanical response techniques, the fate and effects of spilled oil, oil-spill contingency planning and preparedness, spill response training, incident-management systems and spill prevention. Alaskan oil-spill response cooperatives, private consultants, universities, and other state and federal agencies have conducted research under the program.

3.1.2 California Office of Oil Spill Prevention and Response (CAOSPR)

As both a prevention and response organization, CAOSPR has the Department of Fish and Game's public trustee and custodial responsibilities for protecting, managing and restoring the state's fish, wildlife, and plants. It is one of the few state agencies in the nation with both major pollution response authority and public trustee authority for wildlife and habitat. This mandate ensures that prevention, preparedness, restoration and response will provide the best protection for California's natural resources.

In 2014 California expanded the CAOSPR program to cover all state surface waters at risk of oil spills from any source, including pipelines, production facilities, and the increasing shipments of oil transported by railroads. This expansion provided critical administrative funding for industry preparedness, spill response, and continued coordination with local, state and federal government along with industry and non-governmental organizations.

3.1.3 Florida

The Oil Spill Academic Task Force (OSATF) is a consortium of scientists and scholars from institutions in the State University System as well as from five of Florida's private universities and two marine laboratories working in collaboration with the Florida Department of Environmental Protection (DEP). The OSATF brings together expertise and resources to assist the state of Florida and the Gulf region in responding to and studying the Deepwater Horizon oil spill.

The Fish and Wildlife Research Institute's work includes assessment and restoration of ecosystems and studies of freshwater and marine fisheries, aquatic and terrestrial wildlife, imperiled species, and red tides. The institute develops the information science required to analyze and disseminate research products, and engages in outreach activities to complement all programs.

The Florida Marine Spill Analysis System (FMSAS) is a powerful geographic information system (GIS) application that allows users to conduct oil spill planning activities and manage response and mitigation efforts during an actual spill. Spill planning and response activities have always relied on maps and charts to display information. From simple notes on nautical charts to specialized maps showing the location of sensitive resources or the location of an oil slick, many of the essential information components of planning and response actions require geospatial data. The FMSAS is designed to address five aspects of oil spill management:

- Contingency planning;
- On-scene spill tracking and "Resources At Risk" (RAR) analysis;
- Long-term monitoring;
- Damage assessment; and
- General oil spill GIS data management.

3.1.4 Louisiana Applied and Educational Oil Spill Research and Development Program (OSRADP)

The Louisiana OSRADP provided oil spill planners and response personnel with practical, scientifically-sound and cost effective spill prevention, management and mitigation tools for two decades until 2011 when OSRADP became part of the Center for Energy Studies.

3.1.5 Gulf States Marine Fisheries Commission (GSMFC)

The Gulf States Marine Fisheries Commission was established by an act of Congress (P.L. 81-66) in 1949 as a compact of the five Gulf States with a charge to: "to promote better utilization of the fisheries, marine, shell and anadromous, of the seaboard of the Gulf of Mexico, by the development of a joint program for the promotion and protection of such fisheries and the prevention of the physical waste of the fisheries from any cause."

The GSMFC Oil Disaster Recovery Program (ODRP) evolved from the receipt of $15 million dollars in October of 2010 and aims to improve the public perception and confidence in Gulf of

Mexico seafood following the 2010 *Deepwater Horizon* oil disaster. Funding for this program, like that of the post-Katrina Emergency Disaster Recovery Program (EDRP), came from the U.S. Congress following fishery disaster declarations by the U.S. Secretary of Commerce. Scheduled to be completed in September of 2015, the activities under the program are identified through an ad-hoc advisory committee consisting of the marine resource directors from each of the five Gulf of Mexico states. Under this component, multiple post-disaster recovery elements were executed to address issues relative to improving both the perception of and confidence in Gulf of Mexico seafood products.

3.1.6 Minnesota National Crude Oil Spill Fate and Natural Attenuation Site

The Minnesota National Crude Oil Spill Fate and Natural Attenuation Site dates back to 1979, when a dramatic pipeline rupture released 10,000 bbl of crude petroleum to the land surface and shallow subsurface. In 1983, research began at the site through the support of the USGS' Toxic Substances Hydrology Program. Continuing USGS support has allowed hundreds of scientists from across the globe to visit this "underground observatory" and study the effects of a terrestrial crude oil spill including the physical, chemical and biological processes driving the degradation and transport of crude petroleum. Research from the site has been included in more than 200 scientific papers.

In 2008 and 2009, the Minnesota Pollution Control Agency, Enbridge Energy LLC, the USGS and Beltrami County created several agreements to formally establish the "National Crude Oil Spill Research Site in Bemidji, Minn." The objective of these agreements is to create a self-sustaining research facility that brings academic researchers and practitioners (e.g., consultants, petroleum and pipeline industry representatives and pollution control officials) together thereby linking novel ideas to practical, on-the-ground applications.

3.1.7 Pacific States/British Columbia Oil Spill Task Force (PSBCOSTF)

In 1989, following the *Nestucca* and *Exxon Valdez* oil spills, the Governors of Alaska, Washington, Oregon, and California, and the Premier of British Columbia, signed a Memorandum of Agreement that authorized PSBCOSTF. These events highlighted their common concerns regarding oil spill risks and the need for cooperation across shared borders. In June 2001, a revised Memorandum of Cooperation was adopted to include the State of Hawaii and expand the focus to spill preparedness and prevention needs of the 21st century. Now in its third decade, the PSBCOSTF provides a forum where its members can work with stakeholders from the Western US and Canada to implement regional initiatives that protect 56,660 miles of coastline from Alaska to California and the Hawaiian archipelago.

3.1.8 Texas General Land Office (TXGLO)

The TXGLO is a national leader in oil spill research. The TXGLO R&D program has funded groundbreaking work on oil dispersants, shoreline cleaners, bioremediation and high-frequency radar. The R&D program is improving response technology and developing alternative methods for removing oil from coastal waters.

Over the years, the TXGLO has coordinated with other state agencies, the state's higher education institutions and private industry to establish viable research projects for oil spill prevention and response. Funded projects have involved preventive technologies, spill detection, environmental data collection, chemical countermeasures, recovered materials management and in situ burning

The TXGLO, as a NRDA Trustee, acts on behalf of the public to identify the injured natural resources and determine the extent of the impact. They also recover damages from the responsible party to plan and carry out restoration activities. In addition to the TXGLO, two other state agencies are designated as NRDA trustees: the Texas Parks and Wildlife Department (TPWD) and the Texas Commission on Environmental Quality (TCEQ).

3.1.9 Washington Department of Ecology (WADOE)

The WADOE has program offices for oil pollution prevention, preparedness, and response, which include resource damage assessments and recovery. The Department conducts studies on the risks of oil transportation through the state and provides guidance to industry and the public on oil pollution issues. WADOE also manages a Coastal Protection Fund (CPF) that collects monies from oil and hazardous materials spill damage assessments and penalties. The CPF uses the money to fund projects to: restore or enhance public natural resources; investigate long-term effects of oil spills; and develop and implement aquatic land geographic information systems. Funds may also be allocated for R&D on the causes, effects, and removal of pollution caused by the discharge of oil.

3.2 Industry

The oil industry plays an important part in oil pollution research. Industry approaches to exploration, production, transportation, and spill prevention evolve as new techniques are identified or new resources are found. Industry has several research programs to improve their practices to prevent oil spills and to better respond to spills when they occur.

3.2.1 American Petroleum Institute Joint Industry Task Force (API JITF)

In the wake of the *Deepwater Horizon* oil spill of 2010, the petroleum industry launched four JITFs to critically assess capabilities and performance. Each JITF used subject matter experts to identify best practices in offshore drilling operations and oil spill response and to share that knowledge across industry with the goal of ensuring environmental protection through enhanced safety.

The Oil Spill Preparedness and Response JITF examined industry's ability to respond to a "Spill of National Significance (SONS)" and the actual response to the *Deepwater Horizon* oil spill. This program covers:

- Spill Response Planning
- Oils Sensing and Tracking
- Dispersant
- In Situ Burning
- Mechanical recovery
- Shoreline protection
- Alternate response technologies

The industry has also has also begun to improve public outreach in a number of focus areas including:

- Oil spill preparedness and response framework;
- Net environmental benefit analysis (NEBA);
- Role of dispersants in oil spill response;
- Tiered preparedness and response framework;
- Incident management system; and
- Regulatory approval and use of dispersants.

The JITF also initiated subcommittees to address response issues related to inland spills including railroad spills and pipeline emergency response.

3.2.2 American Salvage Association (ASA)

The ASA was created in 2000 as an association of professional salvors dedicated to improving marine casualty response in North American coastal and inland waters. The ASA promotes cooperation among its members and works with Federal and state agencies to identify ways to improve salvage and firefighting response capabilities. The ASA encourages research to identify risks from sunken vessels and uses its members' experience to identify areas for additional research or technology development.

3.2.3 Association of Petroleum Industry Co-op Managers (APICOM)

APICOM, founded in 1972, is an association of unaffiliated petroleum industry oil spill cooperative managers. APICOM exists for the purpose of exchanging information related to the management of an oil spill response cooperative. It also serves as a forum for the exchange of ideas related to oil spill response technologies, operations, regulations and other issues of common interest to its members.

3.2.4 Industry Technical Advisory Committee (ITAC)

The ITAC includes members from the oil spill response community within the oil industry, and other organizations that have oil pollution preparedness and response as their principal goal. ITAC acts as a focal point for technical issues and as a forum for exchanging information on preparedness, oil spill response operations, response technology and response training.

3.2.5 International Maritime Organization (IMO)

The IMO is a specialized agency of the United Nations, which is responsible for measures to improve the safety and security of international shipping and to prevent marine pollution from ships. It is also involved in legal matters, including liability and compensation issues and the facilitation of international maritime traffic. IMO's governing body is the assembly, made up of all 170 Member States, which meets once every two years. The Maritime Safety, Marine Environment Protection, Legal, Technical Co-operation and Facilitation Committees, and a number of sub-committees carry out the main technical work. Since 1967, the IMO has adopted a series of conventions covering prevention of marine pollution by ships, preparedness and response to incidents involving oil and hazardous and noxious substances, prevention of use of harmful anti-fouling systems and the international convention on ballast water management to prevent the spread of harmful aquatic organisms in ballast water.

3.2.6 International Petroleum Industry Environmental Conservation Association (IPIECA)

IPIECA is the global oil and gas industry association for environmental and social issues. It develops, shares, and promotes good practices and knowledge to help the industry improve its environmental and social performance. It is the industry's principal channel of communication with the United Nations.

IPIECA's Oil Spill Working Group (OSWG) was established in 1987 and serves as a key international industry forum to help improve oil spill contingency planning and response around the world. The OSWG aims to improve oil spill preparedness and response around the world by:

- Enabling members to exchange information and best practices
- Supporting industry and government cooperation at all levels
- Encouraging ratification and implementation of relevant international conventions
- Promoting the principle of 'Net Environmental Benefit Analysis' and the 'Tiered Response' approach to designing response strategies; and
- Developing and communicating the industry's views and activities to external audiences'

3.2.7 International Spill Control Organization (ISCO)

The International Spill Control Organization (ISCO) is a not-for-profit organization incorporated in London in 1984 with membership in 36 countries around the world. ISCO aims to raise worldwide preparedness and co-operation in response to oil and chemical spills, to promote technical development and professional competency, and to provide a focus for making the knowledge and experience of spill control professionals available to IMO, United Nations Environment Programme (UNEP), European Commission (EC) and other organizations. ISCO provides organizations with information on experiences, problems solved, and lessons learned by spill responders. They also keep the spill response community informed of new developments and news through their website and newsletters.

3.2.8 International Tanker Owners Pollution Federation (ITOPF)

ITOPF is a not-for-profit organization established on behalf of the world's ship owners and their insurers to promote effective response to marine spills of oil, chemicals, and other hazardous substances. ITOPF provides a range of technical services including emergency response, advice on clean up techniques, pollution damage assessment, assistance with spill response planning, and training. It is recognized and respected globally as a source of objective technical expertise in the area of accidental spills of oil and chemicals from ships and ITOPF is a source of comprehensive information on marine pollution. Investing in R&D is one way ITOPF meets this objective. ITOPF invests in R&D to help fulfill their mission of promoting effective response to marine spills of oil, chemicals and other substances.

3.2.9 Oil Spill Response (OSR) Joint Industry Program (JIP)

The OSR JIP is an initiative of the Oil and Gas Producers (OGP) to address issues related to the Macondo well blowout. In response to the incident, the OGP formed the Global Industry Response Group (GIRG), which was tasked to identify the key issues that could prevent recurrence of such an incident and identify learning opportunities on both the causation, and the subsequent response to the incident. The OSR JIP has initiated discreet projects or supported projects of other groups in many oil spill related subject areas resulting from the OGP GIRG-OSR studies.

3.2.10 Petroleum Environmental Research Forum (PERF)

The PERF is a research and development joint venture, formed to provide a stimulus to and forum for the collection, exchange, and analysis of research information relating to the development of technology for health, environment and safety, waste reduction and system security in the petroleum industry. PERF is a non-profit organization of member corporations in the petroleum industry. PERF does not itself participate in research projects but provides a forum for members to collect, exchange, and research information relating to practical and theoretical science and technology concerning the petroleum industry and a mechanism to establish joint research projects in the field.

3.2.11 Pipeline Research Council International (PRCI)

The PRCI was established in 1952 as the Pipeline Research Committee of the American Gas Association to address the problem of long-running brittle fractures in natural gas transmission pipelines. In substantially solving that problem within two years, the committee demonstrated the benefit of industry collaboration and leveraging voluntary industry funding. Unique among all pipeline research organizations, the mission of PRCI is to be the global leader in collaborative energy pipeline research that provides safe, reliable, environmentally conscious and efficient means of energy delivery. The committee will be used to improve current inspection and integrity assessment technologies, and to promote the development of new technologies for pipeline integrity management.

Some of PRCI's recent research has addressed:

- Corrosion — location and assessment;
- Mechanical damage — location and assessment;
- Right of Way (ROW) monitoring;
- Growth of construction defects;
- Compressor and pump station; and
- Measurement.

3.2.12 Spill Control Association of America (SCAA)

SCAA organized in 1973 to actively promote the interests of all groups within the spill response community. They represent spill response contractors, manufacturers, distributors, consultants, instructors, government and training institutions and corporations working in the industry. SCAA partners with the USCG and the Association of Petroleum Industry Co-op Managers (APICOM) in the quality partnership for marine safety and environmental protection, which was created to improve the effectiveness of spill response and to promote sound risk management among/between private and governmental response organizations.

3.3 Independent Research Interests

Several independent organizations conduct or manage oil pollution research programs. These include non-governmental organizations, non-profit organizations, and committees with a mix of memberships including citizens, industry, and government organizations.

3.3.1 Cook Inlet Regional Citizen's Advisory Committee (CIRCAC)

OPA 90 established CIRCAC to create an avenue for public participation in the oversight of the Cook Inlet oil industry. Since its inception, the CIRCAC has formed environmental monitoring and oil spill prevention programs to promote safe production and transportation of oil in Cook Inlet. These programs seek to develop an understanding of efficacy, fate, transport, and effects of oil and oil treated by various response methods likely to be used on oil spills in the area of concern. It also monitors the biological and chemical environment in Cook Inlet and nearby areas to detect effects of oil industry operations. The CIRCAC also has a Coastal Habitat Mapping Program to assess coastal habitats with an oil spill prevention and response tool that incorporates detailed coastal habitat data.

3.3.2 Gulf of Mexico Alliance (GOMA)

The Gulf State Governors established the Gulf of Mexico Alliance (GOMA) in 2004 in response to the President's Ocean Action Plan. GOMA's mission is to enhance the ecological and economic health of the Gulf region by encouraging collaboration among government agencies, businesses, education providers and non-governmental organizations. It is a state-led network of partners working together on projects related to the priority issues identified by the Governors in early discussions. The GOMA structure allows federal and state agency partners to focus funding priorities on the needs of the Gulf, and it provides a forum to share knowledge, expertise, and collaborate to reduce duplication of efforts.

3.3.3 Gulf of Mexico Research Initiative (GoMRI)

On May 24, 2010, shortly after the *Deepwater Horizon* oil spill, BP announced a $500 million commitment to fund a Gulf of Mexico Research Initiative (GoMRI), a 10-year independent research program designed to study the effects of the oil spill and its associated response on the environment and public health in the Gulf of Mexico. GoMRI awards funds competitively for scientists to investigate the impacts of the oil, dispersed oil, and dispersants on the ecosystems of the Gulf of Mexico and affected coastal States in a broad context of improving fundamental understanding of the dynamics of such events and their environmental stresses and public health implications. GoMRI also seeks to develop improved spill mitigation, oil and gas detection, characterization and remediation technologies.

As directed by an independent 20-member Research Board, GoMRI issues grants for independent scientific research conducted primarily at academic institutions in the U.S. Gulf Coast States. However, institutions from outside the Gulf region, as well as for-profit entities, can participate. The funds are distributed using peer evaluations (National Science Board Process) and are used strictly for research activities such as sampling, modeling and studies, but not acquisition of infrastructure. Researchers are required to publish their results in peer-reviewed scientific journals with no requirement for BP approval.

The ultimate goal of GoMRI is to improve society's ability to understand, respond to and mitigate the impacts of petroleum pollution and related stressors of the marine and coastal ecosystems, with an emphasis on conditions found in the Gulf of Mexico. Knowledge accrued will be applied to restoration and to improving the long-term environmental health of the Gulf of Mexico.

3.3.4 Gulf Restoration Science Programs Ad Hoc Coordination Forum

The Gulf Restoration Science Programs Ad Hoc Coordination Forum serves to provide regular communication and coordination on Gulf of Mexico restoration related science between the ecological sciences programs funded from criminal penalties, settlement agreements, and programs funded due to the Deepwater Horizon oil spill.

3.3.5 National Academy of Sciences Gulf Research Program (GRP)

As part of the criminal settlement agreements following the *Deepwater Horizon* Oil Spill, the federal government asked the National Academy of Sciences (NAS) to establish a new program to fund and conduct activities to enhance oil system safety, human health, and environmental resources in the Gulf of Mexico and other U.S. outer continental shelf regions that support oil and gas production. The settlement agreements provide a total of $500 million over the first five years of the 30-year program. The Gulf Research Program works to enhance oil system safety and the protection of human health and the environment in the Gulf of Mexico and other U.S. outer continental shelf areas by seeking to improve understanding of the region's interconnecting human, environmental, and energy systems and fostering application of these insights to benefit Gulf communities, ecosystems, and the Nation. Initial funding of projects began in 2015.

3.3.6 National Fish and Wildlife Federation (NFWF)

Congress created NFWF in 1984. They serve as a non-profit agency to aid in the protection and restoration of fish and wildlife and their habitats. The BP and Transocean Settlement Agreements with the United States established NFWF's Gulf Environmental Benefit Fund to support projects that remedy harm to natural resources (habitats, species) where there has been injury to, or destruction of, loss of, or loss of use of those resources resulting from the *Deepwater Horizon* oil spill. The Fund will distribute $2.544 billion for projects that contribute significantly to restoring and maintaining the ecological functions of landscape-scale coastal habitats, ensuring long-term viability and resilience of habitats, restoring and maintaining the ecological integrity of priority coastal bays and estuaries, and replenishing and protecting living resources.

3.3.7 Ocean Energy Safety Institute (OESI)

The OESI was established under BSEE sponsorship to facilitate research and development, training of Federal workers to remain current on state-of the art technology associated with oil and gas development. It provides recommendations and technical assistance on the determination of Best Available and Safest Technology (BAST), and implementation of operational improvements in the areas of offshore drilling safety and environmental protection, blowout containment and oil spill response. The OESI is a collaborative initiative involving government, academia and scientific experts.

The Texas A&M Engineering Experiment Station's (TEES) Mary Kay O'Connor Process Safety Center manages the OESI, in partnership with the University of Texas at Austin and the University of Houston. The OESI provides a forum for dialogue, shared learning and cooperative research among academia, government, industry, and other non-governmental organizations, in offshore energy-related technologies and activities that ensure safe and environmentally responsible offshore operations.

Specific objectives of OESI are:

- Develop a program of research, technical assistance, and education that serves as a center of expertise in offshore oil and gas exploration, development, and production technology, including technology specific to deepwater and Arctic exploration and development;
- Provide recommendations and technical assistance to the Bureau of Safety and Environmental Enforcement (BSEE) and the Bureau of Ocean Energy Management (BOEM) related to emerging technologies and the determination of BAST, and environmentally sound oil and gas development practices on the Outer Continental Shelf (OCS);
- Provide recommendations and technical assistance related to geological and geophysical sciences relevant to understanding the technical challenges of exploration and development, such as reservoir characteristics, geohazards, and worst case discharge analyses;
- Develop and maintain a domestic and international equipment failure reporting system and database of critical equipment failures related to control of the well that will allow the Institute to identify reliability issues and industry trends. This system should engage both the user and manufacturer of the equipment;
- Engage employees of the Federal agencies to participate in research and training to remain current on state-of-the-art technology associated with offshore oil and gas development;
- Promote collaboration among Federal agencies, industry, standards organizations, academia, and the National Academy of Sciences.

3.3.8 Oil Spill Recovery Institute (OSRI)

OPA 90 established OSRI (http://pws-osri.org/) in response to the 1989 *Exxon Valdez* oil spill. The Prince William Sound Science Center, a non-profit research and education organization located in Cordova, Alaska, administers and houses OSRI. The Congressional mandate given to OSRI is to: 1) identify and develop the best available techniques, equipment and materials for dealing with oil spills in the Arctic and sub-Arctic marine environment; 2) complement federal and state damage assessment efforts and determine, document, assess and understand the long-range effects of Arctic and sub-Arctic oil spills on the natural resources of Prince William Sound; and, 3) understand and document the effects to the environment, the economy and the lifestyle and well-being of the people who are dependent on those resources. Subsequent legislation has provided OSRI with a funding mechanism to assure the research continues as long as oil exploration and development occurs in Alaska. Since 1998, OSRI has awarded approximately one million dollars a year to support a wide range of projects.

3.3.9 Pew Charitable Trusts (PCT) Arctic Science Program

The PCT's Arctic Science Program engages in numerous scientific activities to support conservation campaigns throughout the Arctic. These efforts include original fieldwork, analyses of existing data, and the sharing of scientific findings with a range of audiences. Scientists provide expertise on marine conservation-related issues to the U.S., Canada, Greenland, and elsewhere.

3.3.10 Prince William Sound Regional Citizen's Advisory Committee (PWSRCAC)

OPA 90 established the PWSRCAC to promote partnership and cooperation among local citizens, industry and government. The PWSRCAC conducts long-term environmental monitoring program and oil spill prevention programs to promote safe production and transportation of oil in Prince William Sound. Its programs include a hydrocarbon toxicity project to study and address the gaps in knowledge regarding chronic toxic effects of oil, dispersed oil, and *in-situ* burn residue under study conditions similar to the cold marine Alaskan waters.

3.3.11 Ship Structure Committee

Since its inception in 1943, the Ship Structure Committee has sponsored and coordinated R&D projects to improve ship design, construction, operation, inspection, maintenance, and repair methodologies. The Committee's mission is to enhance the safety of life at sea, promote technology and education advancements in marine transportation, and to protect the marine environment. This is done through advocating, participating in, and supporting cooperative R&D in structural design, life cycle risk management of marine structures, and production technologies. The Committee includes representatives from the USCG, Navy, MARAD, American Bureau of Shipping, Transport Canada, Defense Research and Development Canada Atlantic, and the Society of Naval Architects and Engineers.

3.4 Academia

Extensive oil pollution research is conducted at academic institutions, either individually or as part of university consortia. These entities provide opportunities to explore basic and applied scientific concepts to address oil pollution issues.

3.4.1 Gulf of Mexico Research Consortia

Several university research consortia have been created to study the effects of the Deepwater Horizon oil spill. These consortia bring together researchers from universities, research institutes and other academic entities to collaborate on scientific studies in the Gulf of Mexico. The consortia activities combine research with scientific knowledge of the ecosystems of the Gulf of Mexico to advance the understanding of interactions that occurred and continue to occur among the marine and coastal ecosystems, oil, and dispersants produced by the oil spill.

GoMRI (see Section 3.3.3) provides funding for these consortia or their individual studies. To date, GoMRI issued four one-year block grants in 2010 followed by a series of Request for Proposals (RFPs) for academic consortia and individual investigators to propose research ideas. To date, GoMRI funded 15 different consortia in two rounds of grants, as shown on Table 3-1. In their funding decisions, GoMRI emphasizes: interdisciplinary science and technology involving experts in physical, chemical, geological, and biological oceanography; marine biology; coastal and reef ecosystems, fisheries and wildlife ecology; public health; and associated development of physical, chemical, and biological instrumentation, advanced modeling, and informatics. The activities combine research with scientific knowledge of the ecosystems of the Gulf of Mexico to advance the understanding of interactions that occurred and continue to occur among the marine and coastal ecosystems, oil, and dispersants produced by the oil spill.

Table 4-1: GoMRI-funded Consortia 2010-2014

Consortia	2010 Block Grants	2011 Consortia	2014 Consortia
Florida Inst. of Oceanography	X		
Louisiana State University (LSU)	X		
Marine Environmental Science Consortium	X		
Northern Gulf Institute	X		
Center for Integrated Modeling and Analysis of Gulf Ecosystems (C-IMAGE)		X	X
Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE)		X	X
Consortium for the Molecular Engineering of Dispersant Systems (C-MEDS)		X	
Coastal Waters Consortium (CWC)		X	X
Gulf of Mexico Integrated Spill Response Consortium		X	

(GISR)		
Deepsea to Coast Connectivity in the Eastern Gulf of Mexico (DEEP-C)	X	
Dispersion Research on Oil: Physics and Plankton Studies (DROPPS)	X	X
Ecosystem Impacts of Oil and Gas Inputs to the Gulf (ECOGIG)	X	X
Aggregation and Degradation of Dispersants and Oil by Microbial Exopolymers (ADDOMEx)		X
Alabama Center for Ecological Resilience (ACER)		X
Consortium for Oil Spill Exposure Pathways in Coastal River-Dominated Ecosystems (CONCORDE)		X
Consortium for Resilient Gulf Communities (CRGC)		X
Deep-Pelagic Nekton Dynamics of the Gulf of Mexico (DEEPEND)		X
Littoral Acoustic Demonstration Center - Gulf Ecological Monitoring and Modeling (LADC-GEMM)		X
Relationship of Effects of Cardiac Outcomes in Fish for Validation of Ecological Risk (RECOVER)		X

3.4.2 Gulf of Mexico University Research Collaborative (GOMURC)

Universities across five U.S. Gulf of Mexico states initiated several marine research consortia over the past decades. GOMURC's region-wide alliance of these consortia promotes large-scale, long-term research initiatives required to address Gulf ecosystem-wide stressors such as oil spills, hurricanes, and climate change. GOMURC's mission goals and objectives include advocating for science and education activities that support science-based policies to restore and sustain Gulf natural resources and economy. The following five university consortia members of GOMURC represent 80 universities in the Gulf States:

- Alabama Marine Environmental Sciences Consortium, led by Dauphin Island Sea Lab;
- Florida Institute of Oceanography (FIO), led by University of South Florida;
- Louisiana Universities Gulf Research Collaborative, led by Louisiana State University;
- Mississippi Research Consortium, led by University of Southern Mississippi; and
- Texas Research Consortium, led by the Texas A&M University-Corpus Christi

3.4.3 Harte Research Institute for Gulf of Mexico Studies

The Harte Research Institute, an endowed research component of Texas A&M University-Corpus Christi, is dedicated to advancing the long-term sustainable use and conservation of the Gulf of Mexico. The Institute serves as a research center of excellence in generating and disseminating knowledge about the Gulf of Mexico ecosystem and its critical role in the economies of the North American region. The Institute's ecosystems group focuses on environmental flows and the effects of deep sea oil and gas activities.

3.4.4 NOAA's Sea Grant Program

NOAA's National Sea Grant College Program is a network of 33 individual programs located in universities in every coastal and Great Lakes state, Puerto Rico, Lake Champlain and Guam. These programs serve as the core of a dynamic, national university-based network of over 300 institutions involving more than 3,000 scientists, engineers, educators, students and outreach experts. The network engages the power of academia and a wide variety of partners to address issues such as coastal hazards, sustainable coastal development, and seafood safety.

3.4.5 National University Rail (NURail) Center

In January 2012, the U.S. Department of Transportation awarded a grant of $3.5 million to a multi-university consortium led by University of Illinois Urbana (UIUC) to establish a rail transportation and engineering research center. Headquartered within the Department of Civil and Environmental Engineering at UICC, NURail is a consortium of seven partner colleges and universities with a combination of strengths in railway transportation engineering research and education in North America. The NURail is the first University Transportation Center (UTC) focused solely on rail and concentrates on rail education and research to improve railroad safety, efficiency and reliability. Particular focus is on challenges associated with rail corridors in which higher-speed passenger trains share infrastructure with freight trains.

The NURail has identified six thematic research topics that will be the subject of strategic development planning and ongoing technical research:

- Integrated railroad vehicle/track interaction and dynamic;
- Railroad safety and risk;
- Rail network capacity analysis and planning,
- Urban, regional and high-speed passenger rail implementation
- Multimodal freight transportation; and
- Funding, finance, community and economic development.

3.4.6 Oil Spill Academic Task Force (OSATF)

The Oil Spill Academic Task Force (OSATF) is a consortium of scientists and scholars from institutions in Florida's State University System as well as from five of Florida's private universities and two marine laboratories working in collaboration with the Florida Department of Environmental Protection (DEP). The OSATF brings together expertise and resources to assist the state of Florida and the Gulf region in responding to and studying the Deepwater Horizon oil spill.

3.4.7 Scripps Institution of Oceanography (SIO)

SIO, a department of the University of California San Diego, is one of the oldest and largest centers for ocean, earth and atmospheric science research, education, and public service in the world. Research at Scripps encompasses physical, chemical, biological, geological, and geophysical studies of the oceans, earth, and planets. Researchers at SIO engage in basic research to expand our knowledge and understanding of natural hazards, including earthquakes, volcanoes, tsunamis, storm waves, floods, erosion, hurricanes, tornadoes, wildfires, and harmful algal blooms, as well as their impacts.

Some important programs include: the Southern California Coastal Ocean Observing System's real-time surface current mapping network for tracking and mitigating response to oil spills and improving search and rescue operations and safe boating; and the ANZA Seismic Network, providing real-time seismic information for Southern California.

3.4.8 UAA/SIT Center of Excellence for Maritime Research (CMR)

The DHS Science and Technology (S&T) Directorate selected the University of Alaska Anchorage (UAA) and the Stevens Institute of Technology (SIT) as co-leads for a Center of Excellence for Maritime Research (CMR). The CMR will provide research to identify better ways to create transparency in the maritime domain along coastal regions and inland waterways, while integrating information and intelligence among stakeholders. DHS charged the CMR to develop new ideas to address these challenges, provide a scientific basis, and develop new approaches for USCG and other DHS maritime missions.

3.4.9 UAF Arctic Center for Oil-Spill Research & Education (A-CORE)

The University of Alaska-Fairbanks (UAF) A-CORE is a leading academic institution in Arctic research that focuses on research applicable to Arctic oil spills. A-CORE partners with state and federal agencies, industry, and other academic institutions to support wise decision-making concerning Arctic oil spill response and prevention by working to fill gaps in existing knowledge.

In March 2015, UAF began operating the *Sikuliaq*, a new 261-foot oceanographic research vessel owned by the National Science Foundation. The *Sikuliaq* can cut through 2.5 feet of first-year sea ice and is the only ice-capable vessel in the U.S. academic research fleet. The ship is outfitted with state-of-the-art equipment to bring scientists to previously inaccessible ice-choked polar regions of the globe. The *Sikuliaq* will advance polar and sub-polar research. *Sikuliaq* can accommodate up to 24 scientists and students, including those with disabilities.

3.4.10 U.S. Coast Guard Academy

The United States Coast Guard Academy is the Department of Homeland Security's only institution of higher education. Academy cadets as well as faculty continue to undertake academic research in oil spill science, policy, and in marine engineering. The Academy also provides education to cadets in these fields.

The United States Coast Guard established a Center for Arctic Study & Policy (CASP) at the Academy to promote academic research on Arctic policy and strategy by facilitating collaboration, partnerships, and dialogue among specialists from academia, government, tribal organizations, non-governmental organizations (NGOs), industry, and the USCG. CASP serves as an operationally-focused academic think tank to promote research, broaden partnerships, and educate future leaders about the complexities of this unique region. Through collaborative efforts, the Center will promote effective solutions to address present and future Arctic maritime challenges as the Coast Guard increases its Arctic presence.

3.4.11 University of New Hampshire (UNH) Oil Spill Centers

UNH in Durham, NH, administers the Coastal Response Research Center (CRRC) and the Center for Spills in the Environment (CSE). CRRC was established in 2004 as a partnership between the NOAA Office of Response and Restoration (OR&R) and UNH. The CRRC partnership stimulates innovation in spill preparedness, response, assessment, and recovery strategies. The primary purpose of the CRRC is to bring together the resources of non-governmental scientists and the field expertise of OR&R to conduct and oversee basic and applied research, conduct outreach, and encourage strategic partnerships in spill response, assessment and restoration.

The CSE expands the scope of interaction and cooperation with the private sector, other governmental agencies and universities. The CSE involves individuals and institutions, public and private, at local, regional, national and international levels in identifying needs, evaluating and demonstrating promising technologies, and fostering their use as part of new, integrative approaches to response and restoration.

3.4.12 Woods Hole Oceanographic Institution (WHOI)

WHOI is a non-profit oceanographic research organization with a mission to explore and understand the ocean and to educate scientists, students, decision-makers, and the public. WHOI scientists and engineers maintain expertise across a range of oceanographic research areas. They work collaboratively within and across six research departments to advance knowledge of the global ocean and its fundamental importance to other planetary systems. WHOI research provides information of value to a wide range of ICCOPR research areas including pre-spill baseline studies, injury assessment and restoration, and multiple response research areas.

3.5 International Efforts

Oil pollution is a global issue and requires international cooperation and research to address. ICCOPR and its members work cooperatively with other nations and international entities to conduct research and to better respond to oil spills.

3.5.1 Arctic Council

The Ottawa Declaration of 1996 formally established the Arctic Council as a high level intergovernmental forum to provide a means for promoting cooperation, coordination and interaction among the Arctic States, with the involvement of the Arctic indigenous communities and other Arctic inhabitants on common issues, in particular issues of sustainable development and environmental protection. Arctic Council member states are: Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, Russian Federation, Sweden, and the United States.

The Council established a series of guidelines intended to define a set of recommended practices and outline strategic actions for consideration by those responsible for regulation of offshore oil and gas activities (including transportation and related onshore activities) in the Arctic. The goal is for regulators to identify the key aspects related to protection of human health and safety and protection of the environment for the management of offshore activities, remaining sufficiently flexible in the application of these regimes to permit alternative regulatory approaches. In May, 2013, all member agencies of the Arctic Council signed the "Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic," providing support for interactions between all eight parties relative to response and preparedness. The eight Arctic nations have different systems with different emphases on the division of responsibility between the operator and the regulator. The Council's goal is to assist regulators in developing standards that are consistently applied and enforced for all offshore Arctic oil and gas operators.

The Council established an Emergency Prevention, Preparedness and Response Working Group (EPPR) to addresses various aspects of prevention, preparedness and response to environmental emergencies in the Arctic. The goal of the EPPR Working Group is to contribute to the protection of the Arctic environment from the threat or impact that may result from an accidental release of pollutants or radionuclides. In addition, the Working Group considers questions related to the consequences of natural disasters.

3.5.2 Australia

Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) helps to unlock Australia's offshore oil and gas resources through research focused on the safe, efficient and sustainable use of their marine natural resources. CSIRO works with industry, government agencies, and academia to provide scientific knowledge and advice for offshore oil and gas; it conducts research and provides advice on the environmental, economic and social factors associated with the entire oil and gas value chain (CSIRO 2015).

The primary objective for Australia is to develop the knowledge and technology to prevent marine incidents and understand pre-spill ecosystems so should an incident occur Australia is prepared to respond effectively. CSIRO has conducted a significant amount of research in a wide variety of areas that support a broad array of prevention and response initiatives. Recent research projects include:

- BLUElink ocean forecasting technology;
- Hydrocarbon sensor arrays to monitor the movement of hydrocarbons during an oil spill;
- Hydrocarbon fingerprinting technique;
- The Hydrates flow loop simulation techniques to help to prevent pipeline blockages;
- Microbial degradation research;
- Biomarker research;
- Dispersant assessments; and
- Ecotoxicology assessments.

The Australian Maritime Safety Authority (AMSA), a federal government self-funded maritime safety agency established in 1990, is responsible for providing a national response capability for marine pollution. The AMSA administers the "National Plan to Combat Pollution of the Sea by Oil and other Noxious and Hazardous Substances", a cooperative arrangement between the federal, state and northern territory (NT) Governments and the shipping, oil exploration and chemical industries, emergency services, and fire brigades.

The oil industry maintains resources for spills occurring at their facilities. For incidents that may require beyond individual company capabilities, the Australian Institute of Petroleum (AIP) through its Australian Marine Oil Spill Centre (AMOSC) subsidiary has established the AMOS Plan formalizing mutual aid arrangements among member companies.

3.5.3 Canada

Environment Canada (EC) is a diverse science-based organization that implements the Government of Canada's environmental agenda. It provides science and technology to support decisions about the environment. The EC conducts and publishes 80 percent of its research in collaboration with external researchers. The EC operates 15 research institutes and laboratories, seven storm prediction centers, and 32 water survey offices. The EC has worked with EPA, MMS (now BSEE), and the Navy to conduct oil pollution research at the Ohmsett facility since the early 1970s.

The Department of Fisheries and Oceans Canada (DFO) has Canada's most complex and comprehensive science programs, in terms of function and geography. Its program areas applicable to oil pollution research address ecosystem effects of energy production and operational oceanography. The DFO's research on ecosystem effects addresses expanded energy development in Canada, mainly offshore oil and gas, hydroelectricity, and oil sands. The DFO's operational oceanography programs study oceanic processes and circulation patterns to predict the ocean's present and future state, and include ocean modeling, ecosystem modeling, and near-shore processes.

3.5.4 Centre of Documentation, Research and Experimentation on Accidental Water Pollution (CEDRE)

CEDRE is a not-for-profit association created as part of the measures taken in the aftermath of the Amoco Cadiz oil spill. CEDRE's headquarters, technical facilities and the majority of its personnel are based in Brest, Brittany, France. It provides advice and expertise to the authorities responsible for oil spill response for marine waters and inland surface waters. CEDRE's advice and expertise is available to foreign authorities or private companies. CEDRE conducts its own research projects and contributes to French and international research programs. Their main research and development activities focus on themes of: enhancing knowledge in the field of spill response; fate of oil and chemicals on the surface and in the water column; response equipment and product assessments; and spill impact and post-spill monitoring.

3.5.5 China

The China Maritime Safety Administration (MSA), part of the Ministry of Transport, has the mandate to investigate and respond to marine pollution incidents in Chinese waters. The China MSA headquarters in Beijing provides central control with 14 subordinate bureaus and about 100 local branches along the coast and the Yangtze River. In recent years, China promulgated a series of new pollution regulations relating to ships, which progressively came into force in the period 2010-12. These cover a wide range of issues, including oil pollution response planning, pre-spill clean-up arrangements, and the emergency handling of pollution accidents. Regulations have also introduced a domestic ship-source oil pollution compensation fund.

3.5.6 European Union (EU)

Since 1978, the EU has played a vital role in the response to marine pollution and today its role has become even greater with the response coordination ensured by its European Response

Coordination Center (ERRC) and with marine pollution preparedness and response services provided by the European Maritime Safety Agency (EMSA).

EMSA assumes the leading role in ensuring a uniform and effective level of maritime safety, maritime security, prevention of and response to pollution caused by ships as well as response to marine pollution caused by oil and gas installations, and provide technical and scientific assistance to the European Commission and member states. EMSA manages a network of standby at-sea oil spill recovery vessels based in all the regional seas of Europe. These normally commercial vessels that cease their normal activities and quickly move to the scene of the oil spill upon request. The agency also provides satellite imagery for detection and monitoring of oil spills, pollution response experts to give operational and technical assistance, and information service for chemical spills at sea.

In September 2008, the European Commission, the EU's executive body, issued their Communication on 'A European Strategy for Marine and Maritime Research' delineated an action plan for better integration of research between the maritime and marine communities in order to address the problems of marine degradation caused by human activities and develop new technologies for sustainable development of maritime activities.

The European Commission is currently funding projects aimed at developing new technologies to mitigate the effects of pollution in the seas and oceans. The 'Argomarine' project ('Automatic oil spill recognition and geopositioning integrated in a marine monitoring network') is one example.

3.5.7 France

Oil represents approximately one-third of France's total primary energy consumption and that share has been falling over the past 10 years. France imports crude oil through three major sea ports (Marseille, Le Havre, and Saint-Nazaire). France has very little domestic natural gas production, and since the French government banned the use of hydraulic fracturing, France imports natural gas through a variety of cross-border pipelines from the Netherlands, Norway, and Russia. France also imports liquefied natural gas (LNG) from countries around the world, notably Algeria , Nigeria, Qatar, and Egypt.

Response arrangements are governed by the "at sea pollution response" section of ORSEC MARITIME (Organisation de la Réponse de SÉcurité Civile), France's civil defense plan. Responsibility for preparing for and conducting clean-up operations at sea lies with one of three Maritime Préfets (one for the Mediterranean Sea, one for the Atlantic and one for the North Sea/Channel). The Maritime Préfet will work in cooperation with the Secrétariat Général de la Mer who has the authority to access the various stockpiles of equipment. Coordination of sea and shoreline clean-up would be supervised locally by a permanent conference with representatives of the Maritime Préfet and the Préfet of the particular Department concerned.

3.5.8 Kill-Spill

Kill-Spill is an EU-funded research program with the mission to develop highly efficient, economically- and environmentally-viable biotechnological solutions for the clean-up of oil spills caused by maritime transport or offshore oil exploration and related processes. The program will deliver innovative biotechnological tools for oil spills remediation.

These new developments include biosensors to monitor hydrocarbon degradation, new environmentally-friendly dispersants and adsorbents, combined microbial and additives formulations, multifunctional bioremediation agents, and tools for sediments decontamination. The impact and toxicity of these newly developed products will be evaluated; and they will be validated in mesocosms and on actual oil spills.

3.5.9 Mexico

A National Contingency Plan was developed in 1981 by a sub-committee of the Mexican Inter-Departmental Commission for Environmental Health. It aims to establish a national response network and provide overall coordination of resources in the event of a spill. The Mexican navy maintains a regional and local organizational structure to implement the National Plan at these levels. Under the General Law of Ecological Equilibrium and Environmental Protection (LEGEEPA), overall responsibility for oil pollution matters in Mexican ports and territorial waters rests with the Mexican navy. Response to a spill is likely to be initiated through the Navy's Marine Environment Protection Division (PROMAM). Assistance is also likely to be sought from the national oil company, Petróleos Mexicanos (PEMEX).

3.5.10 Norway

As a major energy nation, Norway has a particular responsibility to ensure an adequate energy supply and to develop knowledge and technology for efficient and sustainable energy systems. Norway has significant expertise in petroleum and hydropower science and engineering. In addition, Norway is conducting important research efforts in the field of environment and climate research. Despite extensive recovery of petroleum resources during the past 30 years, the petroleum industry still represents a large potential for future value creation in Norway. Research and technological innovation, combined with strict environmental regulations and other policy instruments, are needed to make the environmental impact of the exploration and production of oil and gas as small as possible.

The Norwegian Government's goal is to be a pioneer in developing an integrated, ecosystem-based management regime for marine areas. The purpose of this management plan is to provide a framework for the sustainable use of natural resources and ecosystem services derived from the North Sea and Skagerrak and at the same time maintain the structure, functioning, productivity and diversity of the area's ecosystems. Norway utilizes its major universities to conduct major research programs with respect to oil and gas.

3.5.11 Russia

The Federal Agency of Maritime and River Transport, part of the Ministry of Transport, is the federal executive body with responsibility for preparedness and response for oil spill incidents in Russia. Oil pollution response is assigned to the State Marine Pollution Control, Salvage and Rescue Administration (MPCSA). The MPCSA is responsible for the Marine Rescue Coordination Centres (MRCC), which serves as the focal point for communication during marine spill incidents at the regional level. The "Federal Contingency Plan on Oil Spill Prevention and Response at Sea“ was adopted by the Ministry of Transport, the Ministry of Natural Resources and the Ministry of Civil Defense, Emergencies and Disaster Response (EMERCOM) in July 2003. The Plan complies with IMO Guidelines on contingency planning. There are three levels of planning: local, regional and federal. Ports, oil terminals, and harbors have local contingency plans and capabilities which, if exceeded, can be supplemented by regional plans and resources.

3.5.12 SINTEF

SINTEF is the largest independent research organization in Scandinavia, which operates in partnership with the Norwegian University of Science and Technology (NTNU) in Trondheim. NTNU personnel work on SINTEF projects, and many SINTEF staff members teach at NTNU. SINTEF is known worldwide for its work on oil spills, dispersants, and is one of the world's largest independent research organizations within the oil spill research community and offers expertise in many areas, including:

- Studies of oil weathering;
- Characterization of oil spills including thickness and chemistry;
- Oil spill identification - "fingerprinting";
- Marine environmental technology development;
- Surface water chemistry;
- Net Environmental Benefit Analysis (NEBA) oil spills in the Arctic; and
- Subsea and deepwater releases.

3.5.13 United Kingdom (UK)

The Department of Energy and Climate Change (DECC) works to insure that the UK has secure, clean, affordable energy supplies and promotes international action to mitigate climate change.

DECC is a ministerial department, supported by nine agencies and public bodies. The Oil and Gas Authority, an executive office of the DECC, works with government and industry to make sure that the UK gets the maximum economic benefit from its oil and gas reserves. The Oil and

Gas Authority is responsible for regulating offshore and onshore oil and gas operations in the UK including:

- Oil and gas licensing;
- Oil and gas exploration and production;
- Oil and gas fields and wells;
- Oil and gas infrastructure; and
- Carbon capture and storage (CCS) licensing.

The Maritime and Coastguard Agency (MCA) is the UK's authority responsible for the provision of response procedures designed to deal with any emergency at sea that threatens or causes actual pollution. The national contingency plan for marine pollution from shipping and offshore installations sets out revised procedures for incident response. The national contingency plan ("National Contingency Plan for Marine Pollution from Shipping and Offshore Installations") underwent a major review in 2000, was revised again in 2006 to take advantage of lessons learned during actual incidents and major exercises, and is currently under review. MCA develops and participates in maritime exercises designed to maintain the operational readiness of its staff and equipment. The Counter Pollution and Response Branch also organizes training courses for local authorities to prepare their staff when responding to shoreline pollution.

3.6 Non-Federal Oil Pollution Testing Facilities

Several non-federal facilities provide opportunities for oil pollution testing.

3.6.1 Bedford Institute of Oceanography Center for Offshore Oil, Gas and Energy Research (BIO COOGER)

The DFO Canada's BIO COOGER, located in Dartmouth, Nova Scotia, maintains a wave tank facility for oil pollution research. Each tank measures 32 m long, 0.6 m wide, and 2 m high (1.5 m water depth; 28,800 L volume). Water from the Bedford Basin of Halifax Harbor is pumped into the tanks through a coarse (25 μm pore size) and fine (5 μm pore size) serial filtration system. The tanks are capable of generating various types of wave energies in either static or flow-through mode. Breaking and non-breaking waves (computer-controlled flat-type wave maker) provide mixing energies to achieve dispersant effectiveness similar to that of field conditions. The tanks are equipped with subsea injection systems from pressurized, heated canisters. Experiments benefit from the ability of the tanks to be drained and cleaned (tank walls, bottom, wave maker and absorbers) after each experiment to remove all oil and surfactants.

3.6.2 CEDRE Technical Facilities

CEDRE's technical facilities cover 300 acres and constitute a completely watertight area, which includes a man-made beach, water body, and a deep-water basin. These facilities allow full scale simulation of real life spills in an environmentally friendly manner. The CEDRE Experimentation Column (CEC) is a tool to study the behavior of a substance as it rises up or settles through the water column. The facilities include a flume tank, or Polludrome, that is designed to simulate offshore, shoreline and river conditions on a pilot scale. The facilities also include a greenhouse for experimentation on living organisms.

3.6.3 Churchill Marine Observatory.

A multi-government, multi-university research centre is being developed in Churchill, Manitoba, Canada. The Churchill Marine Observatory will be a multidisciplinary research facility where researchers will study the detection, impact and mitigation of oil spills in sea ice and investigate issues facing Arctic marine transportation. The research will help address technological, scientific and economic issues pertaining to Arctic marine transportation and oil and gas exploration and development throughout the Arctic. The facility is scheduled to open in 2017.

3.6.4 Ocean Coastal Research Engineering (OCRE)

The National Research Council of Canada's OCRE assists industry and government to develop solutions to engineering challenges within ocean, coastal and river environments with a particular focus on harsh and extreme conditions. The approach includes physical and numerical modeling, engineering analysis, technology development, as well as full scale experiments and field work conducted with the support of a comprehensive suite of world-class model test basins and tanks capable of reproducing a wide range of ice, wave, current and wind conditions. OCRE provides technology and facilities to support problems related to: the Arctic; marine infrastructure, and; marine vehicles. OCRE maintains several testing facilities that provide real world conditions:

- Coastal wave basin;
- Offshore engineering basin;
- Multidirectional wave basin;
- Large area basin;
- Ice tank;
- Coastal wave basin; and
- Multidirectional wave basin.

3.6.5 PRCI Technology Development Center

The Pipeline Research Council International (PRCI) opened its new Technology Development Center (TDC) in Houston, Texas in July 2015. The TDC covers eight acres, including a state-of-the-art pull test facility, an over 20,000 sq. ft. workshop, and test facility with an additional 9,000 sq. ft. of office and meeting space. The TDC will provide the industry with an independent third party site to fully understand the capabilities of current pipeline tools and to guide the development of new technologies needed to push toward that goal.

3.6.6 SINTEF Sealab

SINTEF Sealab is a cooperative effort of SINTEF Fisheries and Aquaculture and the Norwegian University of Science and Technology (NTNU) and offers a variety of experimental facilities covering the key elements of marine food webs. The emphasis is on developing experimental systems that simulate natural processes and mimic the fate, behavior and effects of pollutants in the recipient.

The SINTEF Sealab provides:

- Cold climate laboratories with basin facilities;
- Chemical and microbiological laboratories;
- Ecotoxicological laboratories;
- Oil spill research facilities;
  - Shoreline basins;
  - Simulated seabed basin;
  - Dynamic and static test basins/systems; and
  - Tank facilities for subsea studies.

3.6.7 Southwest Research Institute (SwRI)

The Chemical Engineering Department at SwRI specializes in finding solutions to difficult problems and providing exacting services. Staff expertise and world-class facilities provide services such as wastewater cleanup, catalyst screening, pilot plant design and operation, reaction kinetics and enthalpy analyses. Typical services include;

- Analytical testing;
- Personal safety equipment testing;
- Waste disposal characterization; and
- Waste cleanup.

An Ocean Simulation Lab at SwRI provides government and commercial clients with quality facilities and experienced staff to conduct testing and performance evaluation services in more than 10,500 square feet of air conditioned laboratory space and 12 ocean simulation test chambers that range in pressures to 30,000 psig and sizes to 90-inch diameter. Capabilities are available for the complete evaluation of your marine products including: development of testing procedures; test design; test setup; and static and cyclic structural/pressure/thermal testing.

3.6.8 Texas A&M Corpus Christi Center for Coastal Studies (CCS)

The CCS comprises 10,000 square feet of office and laboratory space within the Carlos F. Truan

Natural Resources Center. The CCS facilities include:

- Plankton laboratory;
- Marine ecotoxicology laboratory;
- Marine invertebrate environmental physiology laboratory; and
- Benthic ecology laboratory.

The National Spill Control School (NSCS) was established in 1977 and was named as a consulting, training, and research resource for the National Response Team in OPA 90. The NSCS offers specialized hands-on OSHA mandated training for professionals and workers in the oil spill, hazardous material (HAZMAT), and emergency management industries as well as others in exploration, production, and transportation who deal with spill prevention, planning, and response.

THIS PAGE INTENTIONALLY LEFT BLANK

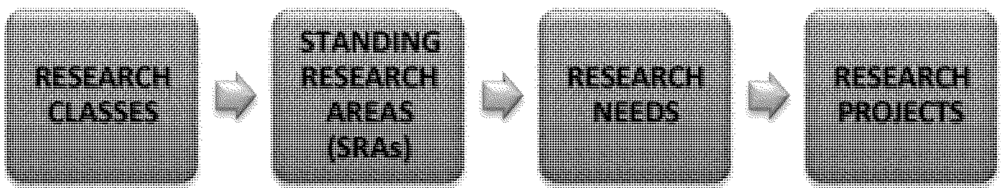
4. Structuring Oil Pollution Research

The field of oil pollution research covers an array of subjects depending on the interests and needs of researcher or the research funding institution. The focus of oil pollution research extends well beyond removing or mitigating spilled oil from the environment to involve other themes such as developing new means for preventing oil discharges, assessing impacts on the natural and human environment, and restoring an affected ecosystem as best as possible to pre-spill conditions. Each of these areas includes a broad spectrum of subjects and topics for oil pollution research, which creates challenges for tracking research activities.

ICCOPR established a new Oil Pollution Research Categorization Framework to provide a common language and planning framework that would enable researchers and interested parties to identify and track research in each topic area. This new approach will be used by ICCOPR to better facilitate communication with Congress, Federal partners, industry, academia, and the general public. It provides a basis for the 15 member organizations to translate their different research needs and perspectives into one federal voice through ICCOPR.

4.1 Introduction to the Oil Spill Research Framework

The Categorization Framework provides a hierarchy of terms to classify, discuss, and prioritize oil pollution research. It is analogous to the taxonomic classification of organisms (i.e., Kingdom, Phylum, Class, Order, Family, Genus, and Species). ICCOPR's oil pollution research classification scheme contains four elements:



Research Classes and Standing Research Areas (SRAs) are generally fixed while the Research Needs and Projects assigned to the SRAs will vary over time. Each of these categorization terms is defined later in this chapter. The following example shows how this new classification scheme works for one project:

Class: Prevention
SRA: Pipeline Systems
Need: Develop advanced pipeline break sensing technologies
Project: Smart Pipeline Network – Seal Sensor System (PHMSA DTRT57-12-C-10050)

Chapter 9 of this OPRTP provides a prioritized list of current Research Needs suggested for 2015-2012 for each SRA. Throughout the six-year life of this Plan, ICCOPR will monitor relevant planned, ongoing, and completed Projects to gauge how government, NGOs, industry, and academia are addressing the published priority Research Needs. ICCOPR will use this information to provide updates on research progress in the Biennial Reports to Congress and to modify or replace existing Research Needs. At the end of the 6-year cycle, ICCOPR will revise the OPRTP for the next 6-year cycle and include a summary of the previous version's accomplishments and a new set of prioritized Research Needs.

4.2 Classes

The overarching Oil Pollution Research Categorization Framework includes four Classes that represent the general groupings of oil spill research: Preparedness, Prevention, Response, and Injury Assessment and Restoration. Figure 4-1 depicts this framework of Classes. It shows that the research in each Class can inform and support the research from other Classes and that the Preparedness Class plays a central role in supporting the others. ICCOPR's member organizations may conduct or support research across one or multiple Classes depending on their specific mission, regulatory responsibilities, and/or expertise.

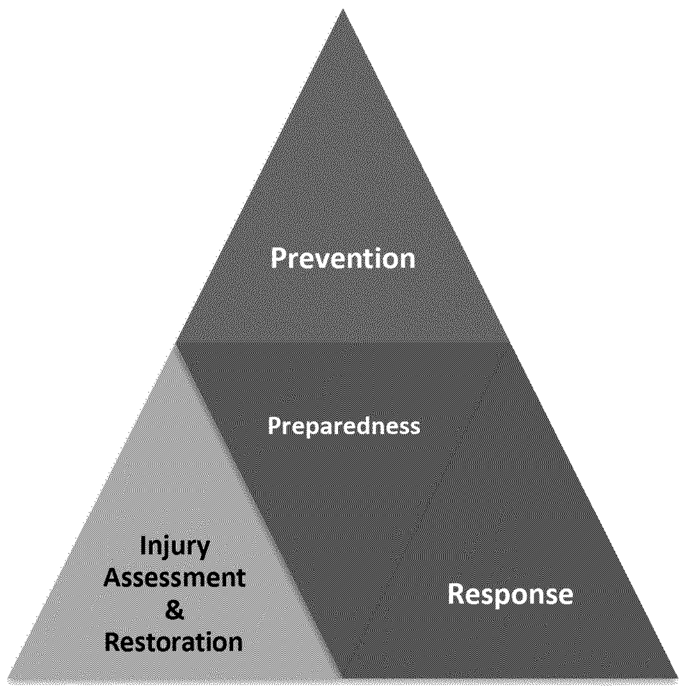


Figure 4.1. The Oil Pollution Research Categorization Framework Classes

The following section describes the research pertinent to each Class.

Prevention Class

Research that supports the development of practices and technologies designed to predict, reduce, or eliminate the likelihood of discharges, or minimize the volume of oil discharges into the environment.

Preparedness Class

Research that supports the activities, programs, and systems developed prior to an oil spill to improve the planning, decision-making and management processes needed for responding to and recovering from oil spills.

Response Class

Research that supports techniques and technologies that address the immediate and short-term effects of an oil spill and encompasses all activities involved in containing, cleaning up, treating, and disposing oil in order to: 1) maintain safety of human life; 2) stabilize a situation to preclude further damage; and, 3) minimize adverse environmental and socioeconomic effects.

Injury Assessment and Restoration Class

Research that involves the collection and analysis of information to: 1) evaluate the nature and extent of environmental, human health, and socioeconomic injuries resulting from an incident; 2) determine the restoration actions needed to restore natural resources and their services to pre-spill conditions; and, 3) make the environment and public whole after interim losses.

4.3 Standing Research Areas (SRAs)

The backbone of ICCOPR's oil pollution research categorization scheme is the SRAs that exist within the four Classes. The SRAs represent the most common research themes encountered for oil spills – many of which have been studied over several decades. Their topical content supports the themes of the Classes for which they are assigned. For this OPRTP, ICCOPR identified 25 SRAs within the four Classes. The number of SRAs will, for the most part, remain consistent; however, changes may occur based on emerging research themes. Specifically, ICCOPR is monitoring on-going activities to determine whether the current SRA structure adequately addresses worker exposure and hydraulic fracturing issues. If not, ICCOPR may add additional SRAs.

Table 4.1 lists the current SRAs by Research Class. ICCOPR uses a numbering scheme to facilitate tracking of research within each SRA (1000 – 4400). The numbering series associated with each SRA is included in the SRA descriptions in the subsections below and in Appendix A.

Table 4-1. Standing Research Areas assigned within the four research Classes.

Prevention	Preparedness	Response	Injury Assessment & Restoration
• Human Error Factors • Offshore Facilities and Systems • Onshore Facilities and Systems • Waterways Management • Vessel Design • Drilling • Rail & Truck Transportation • Pipeline Systems	• Pre-spill Baseline Studies • Response Management Systems	• Structural Damage Assessment and Salvage • At Source Control and Containment • Chemical and Physical Behavior Modeling • Oil Spill Detection and Surveillance • In- and On-water Containment and Recovery • Shore Containment and Recovery • Dispersants • In-situ Burning • Alternative Countermeasures • Oily and Oil Waste Disposal • Bioremediation	• Environmental Impacts and Ecosystem Recovery • Environmental Restoration Methods and Technologies • Human Safety and Health • Sociological and Economic Impacts

4.3.1 Prevention SRAs

ICCOPR has identified eight SRAs that address development of practices and technologies designed to reduce or eliminate the likelihood of oil discharges into the environment and to reduce the potential for consequences of any oil discharges on life, property, and the environment.

4.3.1.1 Human Error Factors [1000 series]

Description: This SRA focuses on how human performance and factors contribute to accidents in the oil production/transportation system. It includes the development of advanced methods and systems for training operational personnel, basic research on operating personnel performance in preventing oil spills (safe navigation on vessels, proper oil transfer practices, analysis/evaluation of equipment monitoring systems, decision-making processes), and the development of methods and technologies to evaluate the ability and knowledge of operating personnel in performing their duties. This may extend to evaluation of the overall management culture and its ability to foster the appropriate organizational safety, preparedness and response operating environment.

Importance: A significant proportion of accidents in oil production/transportation and related industries are attributed to "human errors." A Coast Guard analysis of oil spill causes found that human error factors were responsible for more than one third of non-casualty discharges from ships (USCG, 2012). Non-casualty spills typically include spills from actions such as overfilling of tanks and equipment failures not related to a vessel accident. More than half of these human errors were due to inattention, but also resulted from inadequate training, management and organizational culture. Identifying and solving various human error factors can significantly reduce oil spills at far less cost than more expensive technology-based solutions once the oil is discharged into the environment.

4.3.1.2 Offshore Facilities and Systems [1100 series]

Description: This SRA includes: offshore exploration and development wells, platforms, and well control systems; the methods, techniques, and equipment for system reliability inspections; systems to detect, prevent, and mitigate oil and gas discharges; and equipment to regain control of a well blowout or any other accidental discharge. It also includes transfer equipment, storage units, and piping used to transfer oil within the offshore system and connect the system to transfer pipelines. This technology is relevant for the multiple operating environments of exploration and production activities (e.g., Arctic, shallow, deep and ultra-deep waters).

Importance: Offshore oil and gas facilities are responsible for a significant percentage of oil and natural gas production in the U.S. Globally, three of the ten largest oil spills came from offshore facilities, including the *Deepwater Horizon* oil spill, the largest marine oil spill in U.S. history. (Oil & Gas IQ, 2015) Important new and potential offshore discoveries will continue to be made in frontier environments of increasingly deeper waters and arctic conditions, creating new technical challenges. Research is needed to determine the effects of deepwater conditions, ice forces, and increasingly severe weather conditions (hurricanes, blizzards, etc.) on offshore structures built in these environments. Research is also needed to address issues due to the aging of existing offshore facility infrastructure. Older well spills result from both internal damage (chemical/mechanical corrosion) and external damage (e.g., electrochemical corrosion, mechanical damage, and structural failures). Advanced system designs and the effective application of improved inspection technologies have the potential to detect problems before failures occur, while improved leak detection and well control systems have the ability to identify leaks when they are still small and can be quickly isolated and mitigated to minimize spillage.

4.3.1.3 Onshore Facilities and Systems [1200 series]

Description: This SRA includes designs, techniques, operational procedures and equipment for fixed onshore facilities including wells. It covers inspections and systems to detect, prevent, and mitigate oil and gas discharges from the facilities and their systems, including transfer equipment, storage, and piping.

Importance: A significant number of discharges occur from onshore facilities, coastal bunkering facilities, and cargo transfer operations. Studies conducted by industry estimate that almost a third of oil discharges between 1998 and 2007 occurred at inland facilities subject to EPA's Spill Prevention, Control, and Countermeasures (SPCC) program (API, 2009). Advanced system designs and the effective application of improved inspection technology have the potential to detect, or predict the likelihood of potential failures before they occur. Improved leak detection systems have the ability to identify leaks quickly, potentially reducing the size and impacts of the discharge. It is also important to understand the ability of onshore structures to withstand changes in soil bearing capacity caused by changes in the climate and other factors.

4.3.1.4 Waterways Management [1300 series]

Description: This SRA includes methods, equipment, and integrated systems designed to improve navigation at sea and in ports, rivers, and inland waterways. It includes on-board navigation systems, such as integrated navigation and bridge systems and collision avoidance systems. It also includes systems external to the vessel, such as vessel traffic and tracking systems, navigational aids and piloting systems, as well as includes general research into navigation risks, the effects of navigational safety programs, and the development of decision support tools for waterways management efforts. This SRA includes development of navigational channel maintenance programs and analysis of voyage pre-planning processes.

Importance: A navigation-related marine casualty, such as a collision, allision, or grounding, causes most major spills from vessels underway. Collisions are when two moving vessels run into each other. Allisions are when a moving vessel strikes a stationary object such as a bridge abutment or an anchored ship. Groundings occur when a vessel runs ashore or strikes the bottom. According to ITOPF (2015), these causes accounted for 59 percent of large tanker spills in open waters and about 99 percent of tanker spills in restricted or inland waters. Improving navigation and waterways management, particularly in congested port areas and the approaches to ports, can prevent many of these accidents. In addition, improved waterways management can facilitate safe navigation through the Arctic and other ice-infested waterways as shipping increases in these areas.

4.3.1.5 Vessel Design [1400 series]

Description: This SRA includes the development, physical and numerical modeling, and testing of advanced tanker and barge designs to make these vessels less susceptible to damage and less likely to spill their cargoes into the waterways if an accidental grounding, collision or structural failure occurs. This SRA also includes research on non-tank vessel designs (e.g., double-hulled fuel and lube oil tanks) to minimize the possibility of spillage from collisions, allisions, and groundings.

Importance: OPA 90 required a phased in double-hull program for all tank vessels entering U.S. ports with all remaining tank barges having double hulls by January 1, 2014. Additional research and development is needed to verify these design approaches and investigate other measures to reduce oil spillage from tank vessel damage. IMO Regulation 12A established double-hull fuel tank construction for certain vessels. Congress has likewise considered double-hull fuel tank requirements for non-tank vessels to minimize the possibility of discharges from groundings, collisions, and allisions. In addition, the anticipated increase in shipping in the Arctic seas has created a need to evaluate and develop new vessel designs to ensure safe operations under arctic conditions where ice filled waters and icing conditions around ships and structures create additional structural stresses and corrosion hazards.

4.3.1.6 Drilling [1500 series]

Description: This SRA focuses on: the design, construction, and placement of wells (shallow, deepwater and ultra-deepwater, and onshore); materials, sensors, and systems needed for offshore drilling and production platforms, and well heads/risers; and techniques and equipment for well and facility monitoring and inspection under extreme pressure and temperature environments. Also included are efforts aimed at understanding the chemical and physical characteristics for the full range of petroleum oils under varying conditions of pressure and temperature; predicting their phase/state, behavior and their physical interaction with other materials in the environment (e.g., rock and sediments); and their impact on engineered systems. Example issues include: early kick detection; systems for communicating and responding to changes in downhole parameters; strategies and methods for training operational personnel on the use of advanced technology; systems to detect and prevent oil and gas discharges; and well-head systems and equipment to control wild wells and cap well blowouts.

Importance: The trend toward drilling in deep- and ultra-deepwater and Arctic conditions increases the difficulty in responding to a well blowout and oil spill. Systems to improve safe drilling operations and prevent loss of well control need to adjust as drilling operations advance into deeper waters and the Arctic. Of key importance is the ability to detect changes in rock and fluid properties at the bit-rock interface or even in the rock and fluids ahead of the bit so that measures can be taken to bring the well under control. Advanced system designs and materials, and the effective application of improved sensors, monitoring systems, and more in depth inspection technology have the potential to detect and measure well integrity and prevent failures, while improved leak detection and other systems have the ability to identify leaks while they are still small and can be quickly isolated and mitigated to prevent or minimize spillage. A fundamental understanding of the chemical and phase behavior, especially under extreme conditions of pressure and temperature and effects on engineered systems is critical to effective well construction planning, long-term monitoring, and long-term well integrity.

4.3.1.7 Rail & Truck Transportation [1600 series]

Description: This SRA includes the development and testing of rail and truck transport system designs, operations, and infrastructure to make oil tanks less susceptible to damage and loss of cargo during normal operations, train accidents and derailments, or truck accidents. This SRA includes evaluation of vehicle designs, construction materials, spill prevention devices, and loading/unloading systems and equipment. It also includes evaluations of: the physical and chemical characteristics and behavior of the crude oils being shipped, the effects of those characteristics on the tanks during operations and under accident conditions, and systems to control these characteristics. This SRA also includes evaluations of safety systems and processes to: manage the movement and composition of trains and trucks carrying crude oil, prevent accidents and derailments, select preferred shipping routes, and respond safely to an oil spill emergency.

Importance: North America has experienced a rapid expansion in crude oil supply due to the growing non-conventional oil production activities such as the oil sands products (OSP) from Canada and shale oil from the Bakken fields in North Dakota and Montana as well as the Eagle Ford and Permian Basins in Texas. This expansion in supply resulted in a four-fold increase in the number of crude oil rail car shipments in the past five years. Similarly, crude oil imports from Canada have increased more than 20-fold since 2011. A series of major US crude oil unit train accidents and the Lac Mégantic, Quebec disaster, which resulted in 47 deaths and destroyed much of the town, have underscored the need for safe rail transport of crude oil. The DOT has issued a safety warning that the crude oils being shipped by rail from the Bakken region may be more flammable than traditional heavy crude oil. In May 2015, the DOT issued a final rule to strengthen safety of tank cars transporting flammable liquids.

4.3.1.8 Pipeline Systems [1700 series]

Description: This SRA includes the development, operation, monitoring, and inspection of offshore and onshore pipeline systems used to transport oil between facilities. It covers the pipeline system design, procedures, and equipment for pipeline operations and inspection protocols to prevent, detect, and mitigate oil discharges. Pipeline research under this SRA also includes technologies to prevent (detection/characterization and repair of anomalies before failure) and detect failures, as well as monitor/control systems that can rapidly isolate and shut down operations in order to minimize spillage when failures occur.

Importance: A significant number of oil discharges occur from the more than 182,000 miles of hazardous liquid pipelines in the U.S. PHMSA (2015) pipeline spill statistics document that between 1995 and 2014, there were 2,694 significant hazardous liquid pipeline incidents, 2,614 (97 percent) were onshore. These incidents accounted for the discharge of about 2.2 million barrels and more than three billion dollars in property damages. Several major pipeline spills have occurred causing significant damage to aquatic environments and residential areas. Other pipeline spills in remote areas have gone undetected for long periods of time. Advanced system designs and the effective application of improved inspection technology have the potential to detect potential failures before they occur, while improved detection systems have the ability to identify leaks quickly, potentially reducing the size and effects of the discharge.

4.3.2 Preparedness SRAs

The two SRAs under the Preparedness Class cover research that: 1) supports the collection of baseline data needed to assess the effects of oil spills under the Injury Assessment and Restoration Class, and 2) develops information management tools and systems to improve the ability of response organizations and responders to collect and analyze information during an incident.

4.3.2.1 Pre-spill Baseline Studies [2000 series]

Description: This SRA includes research to characterize and analyze baseline data on the natural environment, human health, and socio-economic characteristics in areas at risk for oil spills. Research includes risk assessments conducted in areas involved in the oil production and transportation systems to identify locations most at risk from pollution events and therefore priority candidates for baseline studies. Baseline information and studies may include: location and population data on species and their habitats, especially ecologically sensitive species; the epidemiology/human health characteristics of people in potential impact areas; and potential community and economic impacts in these areas (e.g., tourism, commercial/recreational fishing, and seafood industry).

Importance: Having baseline information and data enables scientists to compare pre-and post-oil spill changes in natural, human health, and socio-economic systems to support response decision-making and post-spill damage assessments and restoration activities. It is common to conduct a credible post-spill environmental and economic damage assessment without pre-spill baseline information, using reference sites that were not contaminated for comparative studies. However, the availability of pre-spill baseline information makes the post-spill natural and socio-economic damage assessment task much easier, accurate, and more defensible. Essentially, the better environmental and economic systems are understood before a pollution event, the easier it will be to assess changes to those systems, estimate damage and develop appropriate restoration strategies afterward.

4.3.2.2 Response Management Systems [2100 series]

Description: This SRA includes analysis and development of systems to manage how data and information are collected, analyzed, documented, and shared between and among, the planning/preparedness and response communities, the Incident Command System (ICS), and the public. These systems are used to integrate diverse sets of narrative, graphic, and video information and many sets and types of raw and analyzed data. Examples of oil spill information systems include: ICS forms; computer systems; data management software and databases; Geographic Information Systems (GIS); routing, spill and incident management tracking systems; electronic mail and web content; documents, photographs, and video management and archiving systems; communication systems; public information messages and protocols; and graphical displays.

Importance: Information management and decision-making tools are critical to successfully planning for and managing a response and meeting external demands for information about an incident. These systems provide a tool for the incident command to obtain a common operating picture of an incident, to make resource management decisions, and to share appropriate information with all relevant parties. Improving the accuracy and timeliness of the data increases the ability of the incident command to stay abreast of changing situations. Efficient information systems also provide personnel with timely information to give to the public and media, which have a high demand for information to support the 24-hour news cycle.

4.3.3 Response SRAs

The Response Class of research includes 11 SRAs that support improvements to the activities, technologies, techniques, and equipment used during response operations. These SRAs cover all areas from oil detection, behavior modeling, cleanup, and waste disposal.

4.3.3.1 Structural Damage Assessment and Salvage [3000 series]

Description: This SRA includes the development of methodologies and equipment to assess the extent of damage to a stricken vessel caused by collision, allision, grounding, or improper hull stresses during cargo transfers or explosion. This area also includes development of methods and technology to graphically present the implications of various measures that can be implemented to stabilize the vessel's condition, reduce the potential for further pollution, and allow it to be moved safely for repairs or disposal.

Importance: A critical consideration in responding to a casualty is stabilizing the condition of the vessel to prevent loss of life, minimize loss of property, and prevent or minimize discharges of oil. To accomplish this, on-scene personnel must be able to rapidly assess the overall structural integrity and hydrodynamic stability of the vessel to determine the appropriate response measures.

4.3.3.2 At Source Control and Containment [3100 series]

Description: This SRA includes the development of methods, systems, and equipment for containing and recovering the oil at or from the source and for mitigating oil flow from a damaged vessel, onshore/offshore pipeline, and an exploration or production platform, temporarily abandoned (plugged) well, or well head once the spill has begun. Such technologies include well-head capping systems, remotely operated vehicles (ROVs) for subsea containment activities, and patching, plugging and sealing systems. This technology is applicable to all geographic/environmental areas (Arctic, terrestrial, water surface, subsurface shallow, and deep and ultra-deep water).

Importance: The logistical difficulties, enormous costs, and limited success experienced during on-water and shoreline cleanup operations make clear the advantages of containing or recovering oil within, or at least near, the source of the oil flow. Recent technological breakthroughs arose from experiences acquired during the 2010 *Deepwater Horizon* oil spill incident. Additional advances in this area could provide substantial return on R&D investment to contain/recover oil at the source and thereby reduce the extent of contamination and ecological and socio-economic impacts if a spill occurs.

4.3.3.3 Chemical and Physical Behavior Modeling [3200 series]

Description: This SRA includes laboratory and theoretical research and field studies aimed at understanding the behavior and characteristics of the full range of petroleum oils including: behavior and transport in the environment, partitioning of hydrocarbon constituents, and physical interaction with other materials in the environment (rock, sediments, and ice). It includes studies of oil behavior and changes throughout the water column from deepwater blowouts. There is particular interest in non-conventional oils such as those produced in the Bakken and Canadian Tars sands (diluted bitumen (dilbit) and synthetic bitumen (synbit)). It also includes the development and verification of numerical models to predict the surface and subsurface movement and weathering (i.e., spreading, evaporation, dispersion, and dissolution) of oil spills. This SRA also includes methodologies to provide accurate model input data to verify model outputs. This SRA includes development of user-friendly programs to enhance contingency planning and to serve as training aides for spill response teams. Models should be available for various spill scenarios at specific locations for different tidal, current, and weather conditions to pre-plan potential boom deployment strategies and estimate response resource needs.

Importance: Predicting the trajectory (movement) and the weathering of spilled oil, its resultant physical properties and behavior in the water, and the extent of contamination are all critical to identifying the appropriate mix of spill response equipment and countermeasures. A fundamental understanding of the fate (chemical behavior and transport) and effects of oil in the environment is critical to effective contingency planning, response operations management, long-term monitoring, and restoration. In addition, knowledge of longer-term fractionation and transport of hydrocarbons, coupled with potential effects on aquatic resources, provide valuable information to help focus monitoring efforts and develop environmentally-relevant restoration plans.

4.3.3.4 Oil Spill Detection and Surveillance [3300 series]

Description: This SRA principally refers to methods and equipment for characterizing and monitoring oil pre- and post-implementation of response options, and the detection of unknown discharges. This SRA includes surface and subsurface oil spill surveillance including devices, sensors, and systems for detecting and tracking oil spills, determining the area and thickness of the oil slick, and measuring the physical properties of the oil. Examples of equipment considered in this area are: surface oil spill tracking buoys; airborne remote sensors and data analysis systems; fluorometers and light-scattering sensors; and satellite remote sensing data and on/in-water oil detection devices with the ability to conduct nighttime and low light recovery operations. It includes research that provides information to support development of monitoring protocols for subsea and surface responses or improvements to existing ones such as the NRT Atypical guidance or the SMART guidance, as applicable. This SRA also includes evaluation of techniques for autonomous sensing operations and reporting from remote locations where logistical challenges limit human accessibility.

Importance: Finding and characterizing areas of subsurface or submerged oil in onshore (inland) and offshore waters remains a significant research and technology need. Surveillance technologies provide opportunities to locate spills and their source, determine their extent and volume, provide important data to support response operations, and determine the effectiveness of response. The ability to locate concentrations of oil and track slick movements for countermeasures and cleanup planning supports response operations. Thickness and physical properties measurement allow responders to determine the feasibility of mechanical recovery, *in situ* burning and dispersant use. The data obtained from the surveillance can facilitate the efficient deployment of resources for response operations. Surveillance data from response operations can also be useful for improving and validating spill behavior models.

4.3.3.5 In- and On-water Containment and Recovery [3400 series]

Description: This SRA includes the development of methods, equipment, and materials for physically containing and removing oil from the surface of the water, the water column, or on the bottom of the sea/river bed. This SRA focuses on improving traditional equipment such as booms, skimmers, and sorbent materials, as well as developing new approaches to surface containment, and equipment and systems specific to containment and recovery of subsurface oils.

Importance: Mechanical recovery is often the preferred option to physically remove oil from the environment because the use of these devices to respond to oil spills generally does not pose the potential for additional environmental harm. Containment booms are subject to entrainment and splash over when they encounter certain current velocities or wave heights, thereby reducing their containment effectiveness. Developing new boom designs could improve oil containment across a wider range of environmental conditions, including ice-infested and brash-ice infested waters. Mechanical recovery is often the most viable recovery option since it is not subject to agency pre-approval requirements (as are the use of dispersant and *in situ* burning (ISB)). The total average on-water recovery effectiveness for larger spills ranges from 5-30 percent of the oil spilled depending upon the type of oil spilled, ambient conditions, and available equipment. Improvements in the speed of skimmer advance and encounter rates, onboard separation/decanting, and enhanced skimming abilities at higher speeds and wave heights, and rapid systems for temporary oil storage of skimmers could significantly improve mechanical recovery efficiencies. Existing technologies have limited success in recovering oil suspended in the water column or located on the sea/river bed.

4.3.3.6 Shoreline Containment and Recovery [3500 series]

Description: This SRA covers new methods, treating agents, and equipment for removing oil from shorelines, as well as mitigating the environmental impact of oil that cannot be removed. Specifically, this SRA includes water washing and flooding techniques, the use of chemical treating agents, and novel applications of mechanical removal techniques and equipment. It also includes analysis, evaluation and decision-making (risk and benefits) for the use of active shoreline oil removal techniques versus passive naturally-occurring processes.

Importance: Oil spills that impact shorelines often result in oiling of natural resources (e.g., beaches, marshes, coral reefs, mangroves) and man-made structures (e.g., breakwaters, seawalls, piers, vessels). Removing the oil or mitigating the impacts of the oil requires a range of viable technologies that can remove/mitigate the oil while minimizing environmental damage from the technology. Implementing technologies also requires knowledge of the relative benefits of foregoing cleanup activities and allowing natural processes to remove the oil.

4.3.3.7 Dispersants [3600 series]

Description: This SRA addresses the use of chemical products designed to interact with marine oil slicks by reducing the oil/water interfacial tension and breaking up the slick into tiny droplets with the aid of wave or other energy sources. Research areas for dispersants include: developing appropriate dispersant applications for cold weather and deep sea environments; increasing dispersant effectiveness for water surface and subsurface applications (e.g., effective on a wider viscosity and emulsification range, and calm sea conditions); reducing ecological effects of individual dispersant components and combined components in the water column; refining vessel, aircraft, and subsurface application methodologies and equipment; developing enhanced monitoring methods and systems for determining the effectiveness of surface and subsurface application of dispersants; determining how to distinguish physically versus chemically dispersed oil; studying the distribution and impact of the chemicals and dispersed oil in the environment; and understanding regional variations in dispersant performance and environmental effects. This SRA may include characterization to enhance the ability to predict dispersant effectiveness on various oil types and at varying application rates, including the effectiveness of dispersants on weathered/emulsified oils and in a range of water salinities. This SRA also encompasses studies to determine the suitability of subsea application of dispersants in the Arctic region where the unique conditions (e.g., shallow depths, water salinity, ice-infested water, under-ice discharges) could influence their fate and effects. An important supporting activity is the development of an information database on dispersant product effectiveness, application procedures, and effects. Since dispersants shift the risk from the surface to the water column, additional research is needed to address questions about the potential acute and chronic effects of dispersants on water column organisms and populations at various depths.

Importance: Dispersants are an important tool in spill response when it is critical to mitigate oil slicks, especially those that are large and offshore. Refinements in dispersant formulations to improve their effectiveness, reduce environmental effects, and/or increase understanding about their potential benefits and risks, can allow dispersants to remain a viable option, especially for large offshore spills and other areas where mechanical techniques can fall short in reaching desired levels of effectiveness to remediate spilled oil. Research is needed to address environmental tradeoffs, worker and public health exposures and provide the conditions under which they may be used appropriately.

4.3.3.8 In-situ Burning [3700 series]

Description: This SRA includes equipment and techniques required to ignite and sustain combustion of oil spills on the water, along shorelines, and on land. A source of ignition must be present for the mix of fuel (e.g., oil) and oxidant (e.g. oxygen) in a slick to burn. Because slick thickness is a key variable in determining whether the oil will burn, this research area includes development of equipment such as fire-resistant booms and herders to concentrate the slick thickness, and improved ignition devices. This SRA also includes developing knowledge of the conditions under which this equipment and technique can be applied effectively, including evaluation of use in frigid (i.e., Arctic) environments, where cold conditions and ice limit operational effectiveness of mechanical containment and recovery of spilled oil. This SRA also includes research to develop new methods to enhance burn efficiency and burn weathered, emulsified, and more viscous oils. Research into the production of residuals including soot and other ISB residues, and the techniques and equipment to recover these residues is also included in this SRA.

Importance: The *Deepwater Horizon* incident demonstrated that ISB is a very promising technique for removing large amounts of oil from the surface of the water. For example, on a single day (on June 18, 2010), 16 on-water ISBs resulted in removal of approximately 60,000 barrels of oil from the Gulf of Mexico (USCG, 2011). Another benefit of this technology is that it also reduces the extent of onshore disposal of recovered oil. In addition it can be an effective method of mitigating spills on land and in coastal areas by removing the spilled oil from the surface in lieu of the potential for damage caused by certain mechanical removal techniques or longer-term, passive natural degradation processes. An important consideration in Arctic regions is how soot deposition affects the thickness of snow and ice.

4.3.3.9 Alternative Countermeasures [3800 series]

Description: This SRA includes the development and use of various spill response chemicals to treat oil slicks on the surface of the water making the oil more amenable to other recovery techniques, such as mechanical recovery and ISB. These chemicals include solidifiers, herding agents, elasticity modifiers, shoreline pre-treatment agents, and emulsion treating agents (demulsifiers). Development activities include improving chemical formulations, refining application techniques, and conducting studies of effectiveness and environmental effects.

Importance: Alternative countermeasure employing chemicals to treat oil slicks are not frequently used but, in certain cases, can be very effective in improving oil recovery and oil impact mitigation. At present, the countermeasures included in this SRA would typically be used on smaller spills close to shore due to the logistics involved in using them. Their use for larger spills is currently limited. However, development of new formulations of these agents has the potential to increase their utility. Emulsion breakers used on recovered oil could decrease the amount of material for disposal.

4.3.3.10 Oily and Oil Waste Disposal [3900 series]

Description: This SRA includes study and development of analytical methods, procedures, equipment and techniques to manage and dispose of oil, oily water, oiled soils, and oiled debris recovered during both on-water and on land oil pollution incidents. Specific technologies include, but are not limited to, waste segregation, temporary storage, solidification and stabilization prior to landfill disposal or recycling, oil reclamation, incineration, and biological treatment (i.e., land farming and composting). It also includes techniques and equipment for onsite oil-water separation, filtration, and decanting operations that would reduce the volumes of oil/water material that would need to be handled, transported, and disposed.

Importance: Disposal of oil and oiled debris can be a significant problem during major spills, particularly in remote areas. Oil in water tends to emulsify (wave action results in water becoming incorporated into the oil forming "mousse"). Emulsified oil generally occupies a larger volume than the same amount of fresh oil, making waste disposal a significant issue during spill response. In addition to waste recovered during the active response, waste is also generated by decontamination activities, such as cleaning of oiled vessels, hard booms and skimmers, and mechanical shoreline cleanup equipment. Disposal of decontamination waste will likely include the oil, water, and cleaning agents, which further complicates waste disposal options. Research is needed to advance recycling opportunities and disposal treatment technologies for recovered oil waste and reduce the overall waste following a significant oil spill.

4.3.3.11 Bioremediation [4000 series]

Description: This SRA includes research and technology to exploit the capabilities of microorganisms and plants to accelerate the rate of degradation of oil typically through aerobic degradation, but also through anaerobic degradation processes. Bioremediation is largely an *in-situ* technology as *ex-situ* use requires excavation and further manipulations that may have a greater potential for environmental harm. Research and development opportunities include the development of methodologies for the use of nutrient enrichment and possibly microbes to accelerate the biodegradation process on land, a process called bio-augmentation. This topic area also covers research to understand the conditions needed for effective bioremediation in the presence or absence of dispersants, herders, and other chemical agents. In areas such as coastal wetlands, where stranded oil may have penetrated into the anaerobic subsurface, this research area would include studies to wick the oil up to the surface where aerobic conditions and nutrient enrichment may result in enhanced biodegradation. This SRA also includes development of methodologies to apply bioremediation for more effective response and restoration efforts. For purposes of this OPRTP, bioremediation includes phytoremediation (remediation using plants), a longer-term restoration technique.

Importance: Bioremediation in many cases is used as a polishing step to follow mechanical recovery or other ex-situ treatment strategies. Bioremediation is a less-intrusive alternative to mechanical recovery techniques. This is especially important in environmental habitats and sensitive areas that could be seriously damaged by the use of mechanical recovery techniques

4.3.4 Injury Assessment and Restoration SRAs

The four SRAs in the Injury Assessment and Restoration Class address the development of strategies to recovery from the effects of an oil spill by determining the level of effects and the implications of those effects on the environmental and sociological resources of the affected area. These SRAs primarily support the Natural Resource Damage Assessment (NRDA) process as well as the need to improve restoration techniques and determine ways to minimize the adverse effects of response activities.

4.3.4.1 Environmental Impacts and Ecosystem Recovery [4100 series]

Description: This SRA includes laboratory research, field studies, and modeling efforts to better understand and predict the short- and long-term effects of oil spills at the ecosystem level. It includes research into the short- and long-term recovery of various types of environments and the chronic effects of oil spills on habitat, species, recovery and rehabilitation of wildlife, and community structures. This SRA includes the effects of the oil and the countermeasures and cleanup techniques used to remove the oil. It also includes research to determine the rate of ecosystem recovery both with and without countermeasures and cleanup.

Importance: This research provides important feedback on the effectiveness of past responses, forms the basis for future decision-making during spill response, and provides input for damage assessment, restoration planning, and development of decision support tools. Knowledge of the environmental and ecosystem effects of different response measures provides decision-makers the opportunity to identify and select methods that maximize recovery and reduce the adverse effects of response.

4.3.4.2 Environmental Restoration Methods and Technologies [4200 series]

Description: This SRA includes development of methods and technologies to facilitate and accelerate the recovery of resources following an oil spill. It includes research into the effectiveness of approaches for environmental restoration. It also includes evaluations and comparisons of the factors affecting success of the restoration methods and technologies. It also involves studying previous restoration efforts, as well as natural recovery, to better understand ways to improve or enhance future recovery from oil spills.

Importance: OPA 90 mandated restoration activities and specifically required that funds obtained through damage assessment and compensation litigation be expended on restoration activities. However, very few proven methods, technologies, or monitoring protocols exist to support restoration activities. Knowing the conditions affecting the success of the methods and technologies provides decision makers with tools for selecting the approaches that would enhance the chance for successful restoration.

4.3.4.3 Human Safety and Health [4300 series]

Description: This SRA includes studies on the effects of spilled oil and oil spill response activities on human health and safety for both workers and the public. It includes the study of oil weathering throughout the water column and the potential concerns relative to worker health and safety. It focuses on the development of monitoring instruments, procedures, and processes to inform personnel engaged in oil spill response activities, as well as the general public, who could be affected by the oil spill and response options. It also includes studies of the safety of fish and shellfish in a spill area to determine if they are safe to market and consume. Research on seafood safety may include petrochemical toxicology and profiling, risk analysis, sampling and testing methodology development, and risk communications.

Importance: Protecting the health and safety of responders and the public is the highest priority during a response. Potential hazards in dealing with oil include fire and explosion, vapor toxicity, and danger from dermal exposure. Physical health hazards can be acute or chronic. There are processes and procedures that can be implemented to reduce these potential hazards. However, some hazards require a further understanding of how oil behaves to inform the potential concerns relative to worker health and safety. Benzene, for example, can present a potential for chronic health hazards such as leukemia, for which an understanding of oil weathering would inform the needed levels of protection. Response operations conducted on the water or shoreline present inherent dangers to personnel health and safety ranging from trips, falls, and cuts; injuries from equipment accidents; working in extreme weather conditions (e.g., heat stroke and freezing); and working around environmental hazards. Some response options present additional health concerns such as: the chemicals in dispersants and oil, other chemical countermeasures; bioremediation; and ISB fires. An additional aspect of human health and safety is seafood safety, which is a complex topic involving sampling and analytical plans, equipment and methods, and data interpretation to assess the potential effects on the health of consumers. Development of health and safety techniques and equipment to mitigate these hazards helps the incident command meet its fundamental responsibility to safeguard both responders and the public.

4.3.4.4 Sociological and Economic Impacts [4400 series]

Description: This SRA includes studies on how oil spills and the response to oil spills affect the sociological fabric of communities and their economies. Disciplines encompassed in this research area include sociology, economics, behavioral sciences, political science, and law. It also involves studies on risk communication and community resilience.

Importance: Research is needed to improve communication of risk, decrease scientific uncertainty, and address socioeconomic concerns associated with oil spills. Oil spills and spill response may cause high levels of stress and psychological trauma, including post-traumatic stress. These effects may begin at the individual level and frequently spread to other members of families, and communities whose culture and livelihood are dependent upon the waters and shorelines near an oil spill. Unemployment and loss of income are additional stressors on peoples' lives. Oil spills can also adversely affect social relationships and have disastrous effects on specific individuals and communities in areas where livelihoods depend on use of renewable resources (e.g., fishing). An oil spill can affect the economic livelihood and aspirations of a family as well as an entire community. Typically, the commercial and recreational fisheries and tourism industries experience the greatest economic effects, although a significant number of other economic sectors also may be affected. Research that supplies a broad understanding of the human dimensions of oil spill hazards and identifies better ways to engage and share information using risk communication principles could enhance future decisions concerning sociological and economic effects on community stakeholders and assist those communities in successfully overcoming these obstacles.

4.4 Research Needs

This category represents the research gaps that ICCOPR identified within the SRAs. ICCOPR identifies oil pollution Research Needs during the OPRTP planning cycle through a number of means, including:

- Reports on research programs and results;

- Analyses of lessons learned from recent oil spill incidents;
- Data and information shared at various workshops, conferences, and technical and policy meetings;
- Development or enactment of new regulations;
- Input shared and collected from correspondence, quarterly meetings, or scheduled public meetings;
- Numbers and types of research projects conducted/managed by industry, academia, and non-governmental organizations; and
- Forecasts of issues or problems associated with changes or expansion in any aspect of the energy distribution system.

For this FY2015-2021 version of the OPRTP, ICCOPR compiled a new baseline list of Research Needs that incorporates those needs identified in previous versions and new ones identified since 1997 as described in Chapter 9. Future versions of the OPRTP will: 1) update the needs to remove those already addressed; and, 2) add new needs that ICCOPR identifies through the needs identification process.

4.5 Projects

Projects are the specific research experiments and studies conducted by a primary investigator that addresses a Research Need. Projects involve a methodological study or technology development with assigned budgets, resources, and personnel. ICCOPR tracks projects conducted by any entity, not just those conducted specifically by ICCOPR member organizations. ICCOPR recognizes the value of research projects by other entities and encourages its partners from industry, NGOs, state research programs, research institutions, academia, and international organizations to identify and pursue projects that address the needs.

ICCOPR will monitor oil pollution research projects from any identified source and classify identified needs within the Research Categorization Framework by SRA. ICCOPR will use the lists of projects and information on the research results as a basis for assessing how well the Research Needs were addressed.

THIS PAGE INTENTIONALLY LEFT BLANK.

5. Knowledge Transfer and Advancement

ICCOPR's ultimate goal for the research and technology (R&T) program is to advance information, technologies and regulations that increase the effectiveness of oil spill prevention, preparedness, response, and injury assessment and restoration efforts. The R&T planning process emphasizes and strengthens the roles and responsibilities of the member agencies to assure that research advances the capabilities to reduce oil pollution. The degree to which practitioners implement the results of the R&T program will depend upon the success of the research and how well results are communicated to the oil spill response community. As part of the program, ICCOPR promotes continuous improvement by monitoring the state of knowledge and adjusting the program to meet changing needs.

5.1 Factors Affecting Research and Technology Program Success

The success of the federal oil pollution R&T program depends on several factors: 1) funding; 2) continuity of research; 3) field testing; 4) regional issues; 5) development of new researchers; and, 6) public perception. The importance of these factors to the success of the federal program is discussed below.

5.1.1 Funding

A steady funding stream at appropriate levels is a primary factor to support a successful R&T program. Funding for oil pollution research has been a recognized challenge since the passage of OPA 90. In their review of the 1992 OPRTP, the NAS Marine Board (1993) acknowledged the need for steady funding:

> "An important unresolved issue is funding. The continued evolution and effectiveness of the (OPRTP) plan is in doubt because the additional funding authorized by Congress has not been appropriated. Moreover, little funding under OPA 90 is expected. This short term funding approach poses a significant barrier to most multi-year research. For example, scientists cannot undertake basic research dealing with the nature of oil and sea water mixtures and their response to mechanical and chemical treatment, oceanic environments, and time, because several years of laboratory work and additional time for field testing would be required." *(NAS, Marine Board Commission on Engineering Technical Systems, 1993)*

The Marine Board also noted the problems caused by the boom and bust cycle of research and funding efforts for oil spill cleanup technology:

> "Research and development (R&D) related to oil spills follows a boom-and-bust cycle. After catastrophic spills, when the acute effects of oiled beaches, polluted waterways, and dying wildlife are featured in all the media, there is public outcry and political interest, accompanied by calls for action, for more research, and for better prevention and control measures. Later, as acute effects fade, but longer term and less obvious

> problems may continue, public interest-and with it political interest-fade. By the time the calls for action are translated into R&D plans, the interest is gone, and the plans typically are neither supported nor funded. When the next catastrophe occurs, everyone wonders why no one has learned more about how to deal with the problem since the last spill. The phenomenon of cyclical attention and lack of sustained interest and resources, coupled with the natural distribution of research assignments among a group of agencies with different underlying responsibilities, has made it difficult to create a coherently planned R&D program." *(NAS, Marine Board Commission on Engineering Technical Systems, 1993)*

Similarly, the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011) discussed the continued need for funding at an appropriate level:

> "The technology available for cleaning up oil spills has improved only incrementally since 1990. Federal research and development programs in this area are underfunded: In fact, Congress has never appropriated even half the full amount authorized by the Oil Pollution Act of 1990 for oil spill research and development. In addition, the major oil companies have committed minimal resources to in-house research and development related to spill response technology. Oil spill removal organizations are underfunded in general and dedicate few if any resources to research and development*..."*
>
> "Recommendation: Congress should provide mandatory funding for oil spill response research and development and provide incentives for private-sector research and development." *(National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011)*

The oil production and distribution system is constantly changing, posing new challenges to managing oil pollution. Wells are being drilled at increasingly greater water depths and in more challenging environments. A warming Arctic Ocean is expected to lead to greater activity there, both in exploration and transportation. Exploration of onshore shale oils and oil sands products, along with transportation by rail and pipeline is also increasing. The ability of research and technology efforts to keep pace with the challenges will be affected by long-term funding levels.

ICCOPR does not receive funding for research. Instead, ICCOPR members fund research using their agency's annual budget appropriations or the Oil Spill Liability Trust Fund (OSLTF) R&T funds. At this time, ICCOPR agencies with access to the OSLTF R&T funds are the USCG, EPA, BSEE, and PHMSA. However, federal budgetary rules count any funds withdrawn from the OSLTF for research purposes against an agency's overall budget, which means that oil pollution research initiatives still must compete against other agency missions to obtain funding. The National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011) made the following comment on the funding levels for oil pollution research:

> "Specifically, Congress should provide mandatory funding (i.e. funding not subject to the annual appropriations process) at a level equal to or greater than the amount authorized by the Oil Pollution Act of 1990 to increase federal funding for oil spill response research by agencies such as Interior, the Coast Guard, EPA, and NOAA—including NOAA's Office of Response and Restoration."

While mandatory funding, not subject to appropriations, may be impractical, Federal funding for coordinated Federal research, presumably through ICCOPR, is generally recognized as beneficial to the goal of improved prevention of and response to oil spills.

ICCOPR initially used Regional Research Grants authorized by Section 7001(c)(8) of OPA 90 to address regional oil spill issues. The objective of the Regional Research Program was to "coordinate a program of competitive grants to universities or other research institutions, or groups of universities or research institutions, for the purposes of conducting a coordinated research program related to the regional aspects of oil pollution, such as prevention, removal, mitigation, and the effects of discharged oil on regional environments." Congress authorized funding for the program for the fiscal years 1991 through 1995 but not for subsequent years. ICCOPR will consider additional Regional Research Grants if Congress authorizes funding in the future.

5.1.2 Continuity of Research

The ability of research programs or projects to continue to their logical conclusion is an important factor in successfully addressing oil pollution research needs. Changing agency missions, funding priorities, staffing, or site access may interrupt research programs. Breaks in research continuity, if long enough, can result in a "hiatus effect" where key knowledge or learning opportunities are lost. Particularly vulnerable are studies that measure trends over time (i.e., baseline and impact assessment biological studies, oil fate and effects studies, ocean current monitoring). The institutional knowledge resulting from research efforts can also be lost when program lapses or changes prompt employees to leave their federal positions.

5.1.3 Field Testing

ICCOPR recognizes that field testing is a valuable tool to validate laboratory results and to study techniques, treatments and equipment *in situ*. In 1993, the NAS Marine Board recommended that the federal R&T program include controlled field experiments that involve a deliberate, limited discharge of oil to advance research areas (i.e., oil dispersants, ISB, incineration, and bioremediation). The NAS Marine Board noted that laboratory experiments alone cannot replicate real-world process interactions and variables, and accidental spills provide limited learning opportunities because data on pre-spill conditions and/or spill volume usually are lacking. An independent report, "Responding to Oil Spill in the U.S. Arctic Marine Environment", also echoed the need for field testing (NRC, 2014). The report noted that countries such as Norway have consistently supported this type of research by permitting controlled spills when clear research needs, methods, and goals have been identified, and responsible cleanup and monitoring plans have been established.

Field tests may be justified when laboratory or other simulated settings (e.g., test tanks) cannot address specific Research Needs and no other open water research projects have addressed them. Experiments in large test tanks (i.e., Ohmsett) provide opportunities to simulate real environmental conditions and bridge the gap between laboratory and actual field experiments; however, they cannot completely replicate actual field conditions. ICCOPR will continue working with policy makers and permitting authorities to explore field testing opportunities. Field tests may be justified when laboratory or other simulated settings (e.g., test tanks) cannot address specific Research Needs and no other open water research projects have addressed them.

5.1.4 Building the Next Generation of Researchers

The federal oil pollution R&T program needs an adequate pool of researchers and policy makers interested in oil pollution research to replace those that are retiring or leaving for other opportunities. College students need to view the oil pollution management and research fields as a viable career path. Interest in pursuing these areas is strongest in the years following a major spill (i.e. *Exxon Valdez*, *Deepwater Horizon*) and decreases as events fade from national consciousness. Thus, generating and maintaining interest by college students about to enter the workforce in oil spill R&T careers is an important element of ICCOPR's efforts.

Several of the ICCOPR member agencies have programs to encourage students to become interested in oil pollution research or management. NOAA and the University of New Hampshire's Coastal Response Research Center (CRRC), educate students on issues related to oil spills and response and works with other university programs to encourage academic interest in the field. The U.S. Coast Guard Academy includes environmental protection and marine safety topics across its curriculum in many forms ranging from drilling technology and petroleum chemistry to the history of spills of national significance. In particular the Marine and Environmental Science major includes specific courses in geochemistry, analytical chemistry, and petroleum and oil spill science, and the Engineering Department offers marine engineering courses focused on the needs of the prevention community. Cadet research projects, which are part of their curriculum, from the Science and Engineering Departments often address oil spill issues.

NASA's DEVELOP National Program fosters an interdisciplinary research environment for students, where applied science research projects are conducted under the guidance of the agency and its partner science advisors. DEVELOP is unique in that young professionals lead projects that utilize NASA Earth observations to address community concerns and public policy issues, including oil pollution research.

The International Oil Spill Conference (IOSC) Executive Committee, which includes several ICCOPR members, offers a scholarship program and student awards to promote interest in oil pollution research.

ICCOPR also provides annual advice to the NAS GRP on the direction of the GRP program, which includes education and training. A key program objective of the GRP is to support the development of future professionals and leaders in science, industry, health, policy, and education who can apply cross-boundary approaches to critical issues that span oil system safety, human health, and environmental resources.

The DOI's Youth Initiative includes outreach to students at the Ohmsett facility and at the annual Clean Gulf Conference. At the 2014 Clean Gulf Conference several ICCOPR members participated in a day-long outreach session with a local high school's Advanced Placement environmental science class.

5.1.5 Public Perceptions

The NAS Marine Board observed that public reactions and perceptions can play a significant part in making oil spill response decisions, regardless of their scientific validity. Adverse reactions to the use of a technology can lead to political pressures to limit its use. In 2010, public concerns about the use of dispersants during the *Deepwater Horizon* oil spill response prompted interest groups and state agencies to oppose the use of dispersants. Such opposition may increase the need for research to provide additional validation of dispersant safety and efficacy before approval as a response option. The ICCOPR agencies' research programs need to recognize public perceptions about different technologies and factor them into decisions about research initiatives.

5.2 Communicating Research and Technology Efforts

Researchers must effectively communicate their results to the broader oil spill research and response communities to provide the greatest benefit from their efforts. There are many avenues for transferring research knowledge (i.e., meetings, conferences, workshop, seminars, papers, presentations, journal publications, consensus-based best practice reports, and websites of organizations involved or interested in spill response). ICCOPR views communication as a two-way street and uses a variety of mechanisms, discussed below, to transfer research knowledge to stakeholders and to learn of advances by non-federal researchers.

5.2.1 ICCOPR OPRTP

OPA 90 established the ICCOPR OPRTP as the mechanism to inform Congress and the public on the status of oil pollution technologies, research needs and priorities, and agency roles and responsibilities. The 1992 and 1997 versions of the OPRTP provided ICCOPR's assessments of the state of knowledge at that time. This 2015 version updates the assessment of oil pollution

R&T. ICCOPR intends for future versions of the OPRTP to serve as information sharing documents that provide the current federal perspective on oil pollution research. ICCOPR plans to update the OPRTP every six years to maintain timely information and may publish supplements if warranted.

5.2.2 ICCOPR Biennial Reports to Congress

Section 7001(e) of OPA 90 requires that ICCOPR submit a report biennially on its activities and those of its members during the previous two fiscal years and the anticipated activities for the next two fiscal years. The ICCOPR Biennial Reports to Congress serve as a reference document on ICCOPR activities, member initiatives, and planned activities. Appendices to the reports provide listings of publications by ICCOPR member agencies and descriptions of their research projects.

5.2.3 ICCOPR Meetings

ICCOPR conducts quarterly membership meetings and special meetings with interested stakeholders. The quarterly meetings include a session for agencies to present updates and share results of their research and development efforts. These sessions promotes coordination and collaboration among member agencies. The quarterly meetings also include time for presentations from invited speakers to discuss subjects of interest to the membership.

ICCOPR conducts public and other special meetings with outside organizations to discuss their issues and share oil pollution related information. ICCOPR conducted public meetings to gather input as part of efforts to revitalize ICCOPR and to identify areas of concern for future oil pollution research.

5.2.4 Meetings with Non-Federal Entities

ICCOPR participates in meetings with industry, state governments, NGOs, associations, academia, and other nations to exchange information and promote collaboration and cooperation. Stakeholders frequently ask ICCOPR to address these bodies to explain federal research priorities and initiatives. ICCOPR will continue participating in these meetings and encourage the entities to address the ICCOPR priority Research Needs.

5.2.5 Demonstration Projects

Section 7001(c)(6) of OPA 90 directed that ICCOPR conduct Port Oil Pollution Minimization Demonstration Projects in New York, New Orleans, and Los Angeles/Long Beach. The Great Lakes Oil Pollution Research and Development Act of 1990 amended OPA 90 to include a fourth demonstration in ports of the Great Lakes. ICCOPR conducted two demonstration projects in New Orleans (December 1994) and New York (October 1995). After these first two projects were completed, the USCG determined that they were cost prohibitive and ICCOPR agreed that the objectives for the demonstration projects requirement could be met through other means (ICCOPR, 2003). Since 1995, ICCOPR has addressed the objectives through interagency participation in, and support for, regularly scheduled domestic and international oil spill conferences (i.e., IOSC, Interspill, Spillcon).

In 2014, BSEE sponsored a demonstration of oil spill response processes at the 2014 IOSC in Savannah, Georgia. The theme of the On Water and Aerial Technical Demonstration was "A Complete Spill Response System." The objective is to demonstrate oil spill response resources involving new and existing technology configured to increase the response effectiveness through improved detection, tracking and increased encounter and recovery rates.

The 45-minute demonstration on the Savannah River followed a scripted, simulated spill scenario that included: a remote oil detection device that initiated an oil spill alert message with coordinates to the responsible party, spill management team, identified OSROs, and USCG Sector or Captain of the Port and interested parties. Surface oil spill response vessels, unmanned aerial vehicles and submersible response equipment all participated in the joint response effort. A mobile command center managed the demonstration and broadcast information via a live feed to conference participants.

ICCOPR and its member agencies will consider future demonstrations of response technologies within budgetary considerations.

5.2.6 Conferences

Participation in conferences is an important way to communicate research results, showcase technology, and provide opportunities for researchers and response professionals to interact. ICCOPR and its member agencies sponsor, support, and participate in several oil spill-related conferences domestically and internationally. Primary conferences promoted by ICCOPR include:

- International Oil Spill Conference (triennial in U.S.),
- Interspill (triennial in Europe),
- Spillcon (triennial in Australia),
- Clean Pacific (biennial) and Clean Gulf Conferences (annual),
- Offshore Technology Conference (annual),
- Gulf Oil Spill & Ecosystem Science Conference (annual), and
- Arctic Marine Oilspill Program Technical Seminars (annual).

These domestic and international conferences include both technical programs and equipment tradeshows that present the latest issues, products, and technologies available for oil spill and hazardous materials response, spill prevention, marine salvage, cleanup and remediation, professional services, and regulatory compliance.

The American Petroleum Institute (API) and the IOSC Executive Committee, which includes several of the ICCOPR agency representatives, worked to make all papers presented at the IOSC since its inception in 1969 available free of charge on the internet (http://ioscproceedings.org/loi/). This service provides a wealth of information specific to the oil spill research community.

5.2.7 Workshops and Seminars

Workshops and seminars are widely used in the oil pollution control community to bring together professionals to discuss specific topics and challenges. ICCOPR member agencies sponsor workshops on a wide variety of topics that address priority research issues.

5.2.8 Publications

The researchers funded by ICCOPR are encouraged to publish their research in peer reviewed journals, conference proceedings, books, special reports, and other publications. Literature generated from research could be from researchers within the traditional oil spill community or from academic scientists and engineers. Research published in peer-review journals, especially ones with high impact factors have value in oil spill litigation cases.

Examples of high impact factor peer-review journals and publications that address marine pollution topics include:

- *Applied and Environmental Microbiology,*
- *Environmental Science & Technology (SETAC),*
- *Environmental Toxicology and Chemistry,*
- *Human and Environmental Risk Assessment,*
- *Journal of the American Medical Association,*
- *Journal of Petroleum Technology*
- *Journal of Toxicology and Environmental Health,*
- *Marine Pollution Bulletin,*
- *Microbial Ecology Journal of Environmental Monitoring,*
- *Nature,*
- *Science, and*
- *Water Research.*

5.2.9 Newsletters

ICCOPR monitors newsletters published by many organizations that announce news of their activities, highlight specific programs or initiatives, or summarize advancements in R&T. In addition, several of the ICCOPR member agencies also publish newsletters addressing elements of their oil pollution research missions.

5.2.10 Internet and Social Media

ICCOPR and the member agencies use the internet as a tool to provide oil spill research results and news to stakeholders and other users. ICCOPR maintains an internet site (www.uscg.mil/iccopr) to: share documents, provide links to other programs and resources, distribute research reports, announce conferences and other events, and provide news about research developments.

Some of the ICCOPR member agencies maintain websites and are using blogs and social media platforms (i.e., Facebook and Twitter) to share information with the public and researchers.

5.3 Monitoring the Status of Oil Pollution Technologies

The 2015-2021 version of the OPRTP marks a new baseline in ICCOPR's oil pollution research planning efforts, documenting the status of oil pollution Research Needs at the start of the planning process. Future OPRTP revisions, to be issued every six years, will include revised assessments of the status of oil pollution R&T.

Throughout each six-year planning cycle, ICCOPR will track newly identified Research Needs conducted by members, federal partners, NGOs, academia, and industry. ICCOPR will use the Oil Pollution Research Characterization Framework and research protocol described in Chapter 6 of this OPRTP, to compile information on studies that address future priority Research Needs.

ICCOPR will also assess the compiled information to determine the degree to which the priority Research Needs from the previous plan were addressed and then develop a new set of research priorities for the subsequent planning period. ICCOPR may also issue supplements to the OPRTP during a planning cycle to address emerging Research Needs that increase in priority. ICCOPR may periodically review after action reports, GAO reports, and other sources of identified gaps to inform the Oil Pollution Research Characterization Framework for future research needs

THIS PAGE INTENTIONALLY LEFT BLANK.

PART TWO – ESTABLISHING RESEARCH PRIORITIES

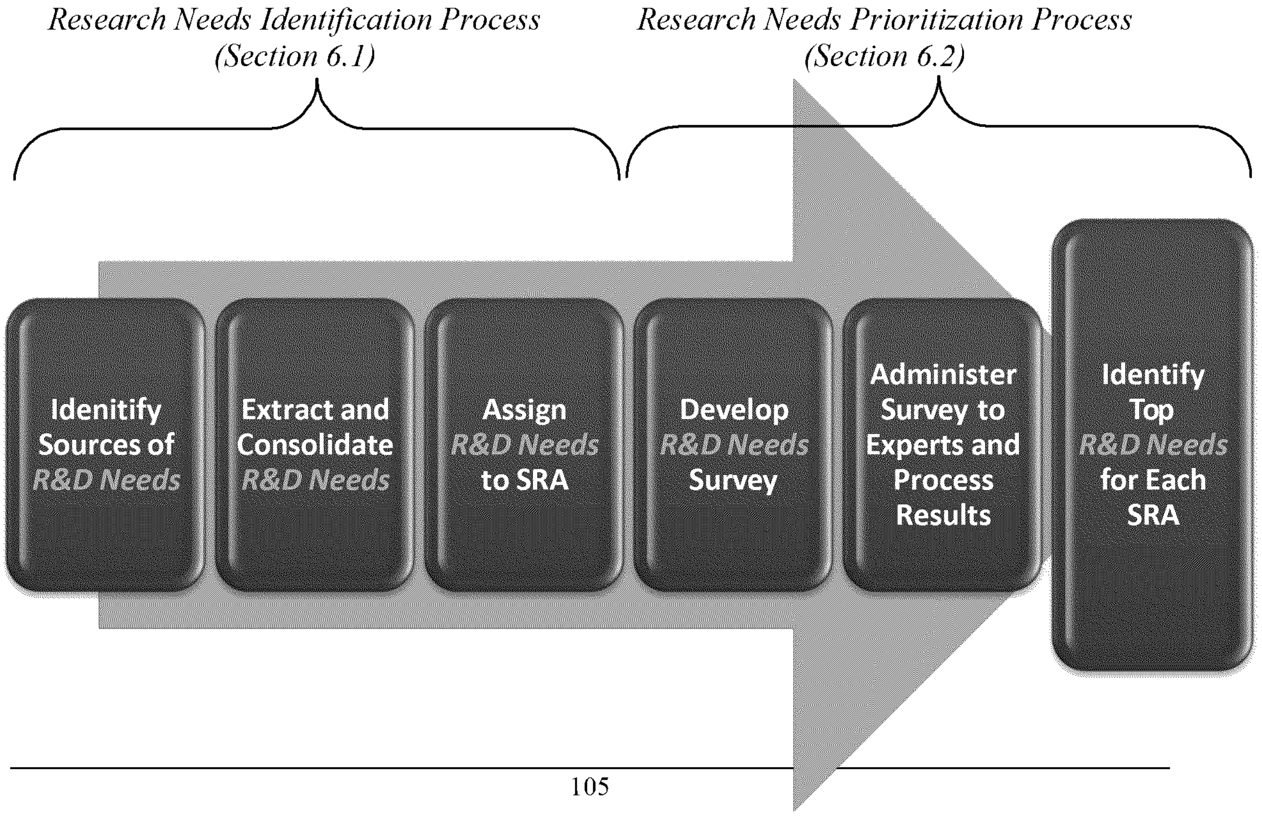
6. Oil Pollution Research Needs Identification and Prioritization Process

A significant number of oil pollution incidents have occurred and a substantial amount of research has been conducted since the completion of the 1997 version of the Oil Pollution Research and Technology Plan (OPRTP). In order to update the OPRTP, ICCOPR needed to develop a process for reviewing the lessons learned from these incidents and addressing any recommendations and gaps noted in the completed research.

ICCOPR established a Research and Technology (R&T) Workgroup with representatives from BSEE, DOE, EPA, NOAA, and USCG to lead development of the revised OPRTP and the Needs Identification and Prioritization Process. The R&T Workgroup was responsible for defining the SRAs, reviewing the Research Needs, and developing the proposed list of research priorities for overall ICCOPR approval.

This chapter describes the systematic process used by the R&T Workgroup to identify and prioritize the nation's future oil pollution Research Needs. Sections 6.1 and 6.2 describe in detail the elements of the process (Figure 6-1). Appendices B through E provide supporting information to the process.

Figure 6-1. Major steps in the Research Needs Identification and Prioritization Processes



6.1 Research Needs Identification Process

The Research Needs identification process consisted of three steps: 1) identification of Research sources; 2) extracting Research Needs and consolidating them into a database; and, 3) assigning Research Needs to SRAs (Figure 6-1). Research Needs were identified through internet searches; discussions with experts; and detailed review of reports, meeting notes and workshop summaries. The R&T Workgroup considered sources that were published prior to initiation of the identification process in 2013. Needs identified in sources published after the process began will be evaluated and prioritized in the next planning cycle.

6.1.1 Identification of Sources of Research Needs

The first step was to identify all possible sources of new Research Needs published since the 1997 version of the OPRT Plan was released. For purposes of this plan, ICCOPR defined sources as: accident case studies; published papers; research reports; workshop or meeting proceedings; white papers; lessons learned; and agency or organizational opinions. More than 50 unique sources were identified as describing Research Needs that should be included in the database. Examples of sources reviewed include: oil spill incident after-action reports; the 1992 and 1997 versions of the OPRTP; Coastal Response Research Center (CRRC) workshop reports; ICCOPR Public Meeting transcripts; interagency reports; research solicitations and publications.

A complete list of the initial sources reviewed can be found in Table 6-1 and Appendix C. Although it was not possible to review every potential source of oil pollution Research Needs since 1997, the sources used in this plan addressed all of the initial set of 23 SRAs and were viewed as representing a comprehensive list.

Table 6-1. List of Sources Reviewed for Research Needs

Sources Reviewed for the ICCOPR Research Needs (by date)
Title 33 U.S. Code Chapter 40 Subchapter IV 2761 (Aug 1990)
Interagency Coordinating Committee on Oil Pollution Research and Technology Plan (April 1992)
Interagency Coordinating Committee on Oil Pollution Research and Technology Plan (1997)
Coastal Response Research Center - Research and Development Priorities: An Oil Spill Workshop (November 2003)

Coastal Response Research Center – Workshop: Research & Development Needs For Making Decisions Regarding Dispersing Oil (September 2005)
National Research Council. Oil Spill Dispersants: Efficacy and Effects. Washington, DC: The National Academies Press (2005)
Potentially Polluting Wrecks in Marine Waters: An Issue Paper Prepared for the 2005 International Oil Spill Conference (2005)
EPA Act 2005 Section 999A(b)(4) DOE National Energy Technology Laboratory Complementary Research Program (2005)
Coastal Response Research Center – Workshop: R&D Needs for Addressing the Human Dimensions of Oil Spills (June 2006)
Coastal Response Research Center - Submerged Oil Workshop Report (December 2006)
DOE 2007 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report (January 2008)
DOE 2009 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report (December 2008)
Coastal Response Research Center - R&D Priorities: Oil Spill Workshop (March 2009)
House of Representatives, Committee on Science & Technology "A New Direction for Federal Oil Spill Research & Development" (June 2009)
DOE 2010 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report (December 2009)
Wreck Oil Removal Program Overview (2009)
Prince William Sound Oil Spill Recovery Institute Research Plan 2011-2015 (February 2010)
Gulf of Mexico Research Initiative: Research Themes (May 2010)
Interagency Coordinating Committee on Oil Pollution Research Public Meetings - West (May 2010)
Pacific States/British Columbia Oil Spill Task Force Letter to Interagency Coordinating Committee on Oil Pollution Research (May 2010)

House of Representatives, Committee on Science & Technology "Deluge of Oil Highlights Research & Technology Needs for Effective Cleanup of Oil Spills" (June 9, 2010)
U.S. Arctic Research Commission - White Paper (July 2010)
Interagency Coordinating Committee on Oil Pollution Research Public Meetings - East (September 2010)
Marine Mammal Commission Letter to Interagency Coordinating Committee on Oil Pollution Research (September 2010)
National Science and Technology Council Joint Subcommittee on Ocean Science and Technology - DWH Oil Spill Principal Investigator Conference Report (October 2010)
Interagency Coordinating Committee on Oil Pollution Research Public Meetings - Gulf (November 2010)
National Academy of Sciences Institutes of Medicine Research priorities for Assessing Health Effects from the Gulf of Mexico Oil Spill (2010)
Deepwater Horizon Incident Specific Preparedness Review (January 2011)
Environmental Protection Agency Draft Oil Spill Research Strategy (January 2011)
National Commission on BP Deepwater Horizon - Final Report (January 2011)
Ultra-Deepwater Advisory Committee 2011 Plan: Comments, Findings and Recommendations (April 2011)
Coastal Response Research Center - Coordinating R&D on Oil Spill Response In the Wake of Deepwater Horizon (July 2011)
Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in the Gulf of Mexico: A Statement of Research Needs (August 2011)
DOE 2011 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report To Congress (August 2011)
U.S. Department of Energy - 2011 Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources R&D Program (August 2011)
Science Advisory Board Review of Environmental Protection Agency's Draft Oil Spill Research Strategy (September 2011)

National Science and Technology Council's Joint Subcommittee on Ocean Science and Technology - Deepwater Horizon Oil Spill Principal Investigator Conference Final Report (October 2011)
Oil Spill Preparedness and Response Joint Industry Task Force (November 2011)
U.S. Geological Survey. An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas (2011)
International Association of Oil and Gas Producers - Joint Industry Programme Solicitation for Expression of Interest (EOI) on Arctic Oil Spills (February 2012)
Coastal Response Research Center - The Future of Dispersant Use in Oil Spill Response Initiative (March 2012)
Ultra-Deepwater Advisory Committee 2012 Plan: Comments, Findings and Recommendations (March 2012)
OESC Letter Recommendations to BSEE Department of the Interior (April 2012)
U.S. Government Accountability Office Oil Dispersants Report (May 2012)
Government and Industry Pipeline Forum (July 2012)
DOE 2012 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report To Congress (August 2012)
OESC Letter Recommendations to BSEE Department of the Interior (August 2012)
U.S. Department of Energy - Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources R&D Program (August 2012)
Ultra-Deepwater Advisory Committee 2013 Draft Plan: Findings and Recommendations (November 2012)
Center for Spills in the Environment Alberta Oil Sands Workshop for Maine DEP and U.S. EPA Region 1 (December 2012)
Bureau of Safety and Environmental Enforcement - BAA Proposed Research on Oil Spill Response Operations (2012)
OESC Letter Recommendations to BSEE Department of the Interior (January 2013)

Center for Spills in the Environment Oil Spill Dispersant Research Workshop Report (March 2013)
Oil Spill Simulants Materials: Workshop Proceedings (March 2013)
University of Washington Transporting Alberta Oil Sands Products: Defining the Issues and Assessing the Risks (March 2013)
Center for Spills in the Environment Alberta Oil Sands Workshop for Washington State Department of Ecology, the Regional Response Team 10 and the Pacific States/British Columbia Oil Spill Task Force (April 2013)
DOE 2013 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report To Congress (June 2013)
NRC An Ecosystem Approach to Assessing the Impact of the Deepwater Horizon Spill in the Gulf of Mexico (2013)
TRB Effect of Diluted Bitumen on Crude Oil Transmission Pipelines Special Report 311 (2013)

During the Prioritization Process, the R&T Workgroup increased the number of SRAs to 25 by adding a new "Rail and Truck Transport" SRA and redefining the Onshore and Offshore facilities SRAs to create a new "Pipeline" SRA. The R&T Workgroup reviewed the new and revised SRAs and determined that additional review of sources for the Rail and Truck Transport SRA and the Onshore Facilities SRA were needed. The R&T Workgroup used experts at PHMSA and the EPA to obtain information on potential missing needs for these two SRAs. Table 6-2 lists the supplemental sources reviewed to determine additional Research Needs.

Table 6-2. List of Supplemental Sources Reviewed for Research Needs

Supplemental Sources Reviewed for the ICCOPR Research Needs (by date)
FRA Research Review Conference (2012)
USDOT Emergency Order on Transport of Bakken Crude Oil (2014)
Federal Railroad Administrator Prepared Remarks - 50th Meeting of the Railroad Safety Advisory Committee (2014)
Discussions with U.S. EPA Office of Solid Waste (2014)

Discussions with PHMSA Office of Pipeline Safety (2014)

6.1.2 Extraction and Consolidation of R&D Needs

A searchable Excel database was created to record information on the source, the applicable environment and the frequency the Research Need was mentioned in the sources reviewed. Initially, more than 900 Research Needs were identified from the source material. After elimination of duplicated Research Needs, the final list consisted of 570 separate Research Needs. This list of 570 Research Needs is located in Appendix B. The original list of more than 900 Research Needs was archived for future use.

6.1.3 Assignment of Research Needs to an SRA

The last step in the Needs Identification Process involved assigning each of the 570 Research Needs to one of the 25 SRAs described in Chapter 4 of this based on the definition of each SRA. Some SRAs had a much larger number of Research Needs than others. SRAs with a large number of needs were further divided into SRA subcategories. The rationale for using subcategories is described in Section 6.2. Figure 6-2 shows an example of the column headings for a typical entry in the Research Needs database.

Figure 6-2 Sample from the Research Needs Database

Standing Research Area (SRA)	SRA Subcategory	Research Need and Key Research Concept	Sources	Physical Location	Sources
Dispersants	Behavior	Constituents - Study chemistry data for individual dispersant components in the oil droplets during the DWH spill.	CRRC - The Future of Dispersant Use in Oil Spill Response Initiative (2012)	Marine and Estuarine	1

6.2 Research Need Prioritization Process

The ICCOPR R&T Workgroup determined that the most effective Needs prioritization process for this OPRTP was to develop a survey (Figure 6-1) that could be distributed to Subject Matter Experts (SMEs) (e.g., scientists, policy makers) familiar with current oil spill research needs. In some areas, there was a need to include state agency, academic, or industry experts in order to find the right expertise to address the R&D Needs questions. The Workgroup determined, however, that in no SRA category or subgroup should non-federal employees exceed the number of Federal SMEs. The survey results helped ICCOPR identify and prioritize the most important Research Needs within each SRA.

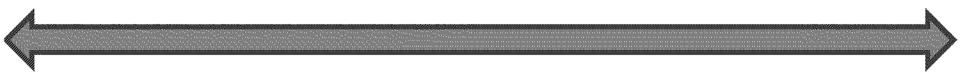
The R&T Workgroup created subcategories for 11 SRAs with a large number of Research Needs to reduce the number of Research Needs that each SME was required to evaluate. The decision to use this approach was based on the experience of UNH Survey Center experts (managers of the survey) who indicated that "survey fatigue" often occurs if a participant is asked to answer a large number of questions, thus affecting the validity of the results. Appendices D through F provide the survey technical report and examples of the survey instrument and results.

The Workgroup compiled a set of proposed priority research Needs for the SRAs and SRA subcategories and presented them to the whole ICCOPR for approval.

6.2.1 Development of Research Needs Survey

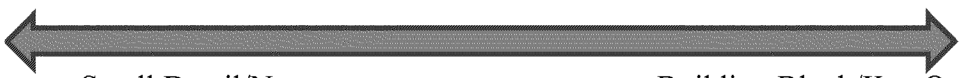
The R&T Workgroup developed and debated a series of key questions that reflected the various aspects of the research process and selected the following questions for the survey:

<u>Question 1</u> - How important is this Research Need in improving any or all of the following: spill prevention, preparedness, response, and/or impact assessment/restoration? (Via sliding scale)



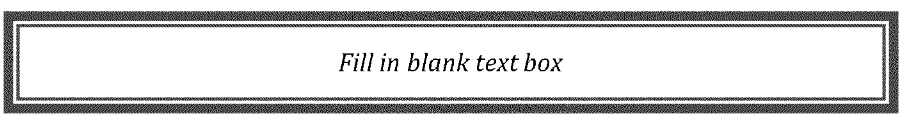
Low Medium High

<u>Question 2</u> - Some research is designed to answer a small detail which refines our understanding of a research problem while other research answers key questions that become the building blocks for further advancements. Please estimate where this Research Need fits in this spectrum of oil pollution research (Via sliding scale)



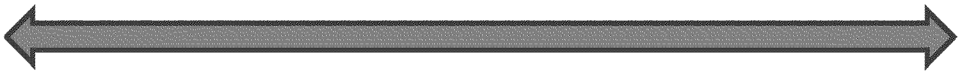
Small Detail/Nuance Building Block/Key Question

<u>Question 3</u> - What would be the estimated cost of the research to answer this Research Need? (Via text box)



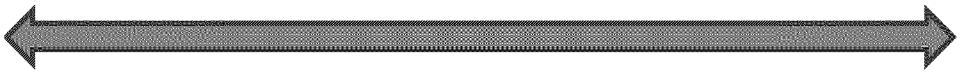
Example 50000000; no commas or dollar sign

Question 4 - How soon would the results of this specific Research Need improve any or all of the following: spill prevention, preparedness, response, or impact assessment/restoration? (Via sliding scale)



Short (<2 year) 2-5 years Long (>5 years)

Question 5 - Solving research problems can require multiple steps. Some research projects take the initial steps while others will be the final step. Please estimate where this Research Need fits in the lifespan of solving a research problem. (Via sliding scale)



Initial Step Final Step

Questions 1-5 were designed to refer to a specific Research Need within the SRA or SRA subcategory that a SME was assigned. Questions 6 and 7 were designed to be asked at the end of the survey and refer to all of the Research Needs evaluated by an SME.

Question 6 - Of the research needs that you reviewed today, which rise to the top? For each, list (up to 3) impediments (other than cost or time to completion) for these top research Needs you identified. (Answers via text box)

Fill in blank text box

Question 7 - Are there any research needs related to this subject area that you feel need to be addressed, but were not on this list? (Answers via text box)

Fill in blank text box

In addition to the questions described above, the R&T Workgroup decided to ask each SME to provide a range of dollar values that they would expect for research projects associated with their assigned SRA or SRA subcategory. This information was intended to allow the R&T Workgroup to calibrate the difference in project costs between SMEs with different backgrounds and different types of research experience. Unfortunately, the number of responses to the inquiry on potential costs were limited and too variable to be of significant value to the decision making process.

The UNH Survey Center built and designed the survey instrument, in conjunction with the CRRC and the R&T Workgroup. A total of 46 separate surveys were developed, one for each SRA or SRA subcategory. Appendix E provides a sample of the survey for one of the Research Needs.

6.2.2 Administration of Survey to SMEs

The R&T Workgroup recruited 285 SMEs to provide at least five SMEs for each of the SRAs and SRA subcategories. These SMEs were selected for their knowledge and expertise in particular SRAs. Responses were received from 223 of these experts; 185 federal employees and 38 non-federal personnel. Survey groups were designed to include a majority of federal employees to avoid Federal Advisory Committee Act (FACA) issues. The UNH Survey Center administered the confidential survey and tabulated the scores.

6.2.3 Processing of Survey Results

In order to determine the highest priority Research Needs, the Survey Center calculated a mean and standard deviation for each of the questions using the answers provided by the SMEs. Questions #3 about costs could not be used in the final scoring because many SMEs did not answer it. The R&T Workgroup weighted the remaining questions based on its knowledge of their importance.

1. How important is this Research Need in improving any or all of the following: spill prevention, preparedness, response, and/or impact assessment/restoration? Weighting **55%**
2. Some research is designed to answer a small detail which refines our understanding of a research problem while other research answers key questions that become the building blocks for further advancements. Weighting **30%**
3. What would be the estimated cost of the research to answer this Research Need? Weighting **0%**
4. How soon would the results of this specific Research Need improve any or all of the following: spill prevention, preparedness, response, or impact assessment/restoration? Weighting **15%**

6.2.4 Identification of Top Priority Research Needs for Each SRA

The priority Research Needs were established based on a review and vote by ICCOPR on the recommended priorities selected by the R&T Workgroup during a series of working sessions during the summer of 2014. The R&T Workgroup's iterative process to select the recommended priorities consisted of the following steps:

- Evaluate statistical ranking and analysis of survey results. The UNH Survey Center provided a ranking of Research Needs by the raw and weighted scores and the standard deviations of both scores. The R&T Workgroup used these initial rankings as a starting point for discussions.

- Review missing Needs. Several SMEs identified potentially missing Research Needs in their responses to Question 7. The R&T Workgroup reviewed the suggestions to determine whether a different SRA or SRA subcategory included the Research Need. The R&T Workgroup added missing Research Needs to the appropriate SRA or SRA subcategory and assigned an appropriate rank based on the members' expert opinion.

- Consolidate research Needs. In many cases, an SRA or SRA subcategory listed similar Research Needs. The R&T Workgroup reviewed these similarities and consolidated them where appropriate. The draft ranking was adjusted to reflect the importance of the consolidated Research Need.

- Determine top three recommended priority Needs. The R&T Workgroup considered several factors in making its final recommendation on the three most important Research Needs for each SRA or SRA subcategory: 1) whether the impediments as listed by the SMEs in answer to Question 6 would prevent or severely limit the potential research to resolve the Need; 2) whether completed or ongoing research had already addressed the Research Need; and 3) did the results of Question 5 and 6 distinguish between similarly ranked Research Needs (however, this last factor was rarely necessary). The R&T Workgroup unanimously agreed upon the top three suggested priority Research Needs for each SRA or SRA subcategory before they were presented to the full ICCOPR.

- Develop the final description of each recommended priority Research Need. The R&T Workgroup reviewed the language of each SRA and the associated priority Research Needs to ensure each description was clearly articulated and consistent with the SRA definition.

- Obtain ICCOPR member feedback. The R&T Workgroup sent its draft list of priorities to the full ICCOPR membership for review and comment. The R&T Workgroup adjudicated the comments through discussions with commenting members and a meeting of the R&T Workgroup.

- Finalize recommended priorities. The R&T Workgroup made its final edits to the recommendations based on the comment adjudication process and met on August 19, 2014 to formally vote on a final set of recommended priorities. The recommendations were sent to the full ICCOPR membership for consideration and adoption.

The full ICCOPR membership discussed the proposed SRA descriptions and the priority Research Needs at the Quarterly Meeting on September 17, 2014. Minor wording changes were made to two Research Needs based on the discussions, and by unanimous vote, ICCOPR adopted the top three priority Needs for each SRA and SRA subcategory as presented in Chapter 9.

7. Noteworthy Oil Spill Incidents

This chapter provides a summary review of noteworthy oil spills since ICCOPR released the 1997 version of the OPRTP. The case studies describe the incidents, the significant causal factors, response issues, and the identified Research Needs. This section is organized chronologically by the type of incident as classified by the National Response Center:

- Vessel Spills (tank and non-tank),
- Offshore Drilling Operations,
- On-shore Pipeline Spills,
- Facility Spills, and
- Railroad Spills.

Information on the spill and response measures described in the case studies was acquired from various sources including: NOAA's Office of Response and Restoration's IncidentNews (www.incidentnews.noaa.gov) for open water spills; the EPA's OSC website (www.epaosc.gov) for inland spills; and State agency information and DOT reports. The Research Needs listed below the incident summaries were taken from Incident Specific Preparedness Reviews (ISPRs), NOAA OR&R reports; and contracted After Action Reviews (AARs) where available. In cases where specific no Research Needs were identified, the R&T Workgroup reviewed the case study information for applicable Research Needs.

7.1 Vessels Spills

Major spills from tankers have been declining globally for several decades according to ITOPF (2015). However, Spills from all vessels remain an on-going concern. The USCG (2012) reported that between 2001 and 2010 there were 20,710 spills from vessels responsible for more than 6.6 million gallons of oil. Tank barges accounted for more than 60 percent of the volume spilled.

TB Penn

In July 2000, the Tank Barge *Penn 460* ruptured and released ~12,600 gallons of No. 6 fuel oil into Narragansett Bay, Rhode Island, an active fishing and lobstering location. The spill oiled two miles of shoreline and numerous birds. Response measures included: the booming of heavily contaminated areas and surface skimming; low pressure flushing of shoreline and sediments; the use of sorbents and snares (passive collection) near the McAllister Hazardous Waste Landfill; a bird capture program for oiled birds;

informational handouts on tar balls to the public; and fishery closures in the immediate area.

This incident is an example of a barge tank rupture that leaked heavy fuel oil into an estuary important for fishing and recreation. There were no specific research recommendations following the spill; however, the response action emphasized the need for further research in the following SRA areas:

- **In- and On-water Containment and Recovery (SRA 3400)** - improve boom and surface skimming equipment.
- **Shore Containment and Recovery (SRA 3500) -** develop improved methods for shoreline cleanup.
- **Environmental Impacts and Recovery (SRA 4100) -** develop improved methods of impact assessment and recovery (for fisheries and avian species).
- **Sociological and Human Impacts (SRA 4400) -** determine impacts to humans related to estuarine spills.

T/V Athos I

In November 2004, the single hull tanker *T/V Athos I* struck a submerged object and spilled approximately 264,000 gallons of heavy Venezuelan crude oil into the Delaware River creating a 20-mile slick that affected 214 miles of shoreline across four states (Pennsylvania, Delaware, New Jersey, and Maryland), with some of the oil submerged below the surface. The investigation by the USCG concluded that the vessel struck a submerged U-shaped pipeline while maneuvering en-route to its berth. The pipeline punctured the vessel's bottom plating in the ballast and cargo tanks.

Response included vessel stabilization and prevention of further discharge; facilitation of vessel traffic, as needed; deployment of protective booms and snares; skimming, collection and recovery of floating oil; enforcement of a safety zone; and collection and rehabilitation of injured wildlife. Economic losses were incurred due to delays in transportation on the Delaware River. The Salem Nuclear Power Plant shut down two reactors because submerged oil was identified in the sediment below some water intakes. The Plant shutdown affected regional electrical generation.

This incident was important for its identification of needed technology improvements including: subsurface object detection and the detection, tracking, mapping and recovery of subsurface and submerged oil. Although there were no specific recommendations for future research as a result of the spill and response actions, this spill highlighted the need for research in the following SRAs:

- **Vessel Design (SRA 1400)** - develop double hull designs.

- **Structural Damage Assessment (SRA 3000) -** develop methods to determine vessel damage.
- **Environmental Impacts and Recovery (SRA 4100) -** develop better methods of wildlife rehabilitation.
- **Sociological and Economic Impacts (SRA 4400) -** study impacts related to primary and secondary economic impacts and costs.

M/V Selendang Ayu

During a large storm in December 2004, the *M/V Selendang Ayu*, carrying a cargo of soybeans, lost power and grounded on the west side of Unalaska Island, Alaska, where it broke into two and released 337,000 gallons of IFO-380 fuel oil, marine diesel, a small amount of lube oil as well as its soybean cargo. Most of the oil was carried onto the rocky shorelines of Makushin and Skan Bays. Half of the vessel sank, while the other half remained afloat, harboring fuel with the potential for additional releases.

Response measures included employing SCAT, an assessment process used for all spills where shorelines are impacted, and manual shoreline cleanup. The potential of an additional release from the floating half of the vessel triggered testing and approval for dispersants and *in situ* burning (ISB), which were not employed. After the initial response, cleanup was halted until April 2005 due to deteriorating winter weather conditions. In the spring, most shorelines were manually cleaned and dry mechanical tilling and berm relocation techniques were used where appropriate. Response actions continued during the weather-permitting seasons until June 2006.

This incident highlighted the difficulty of response operations in the Arctic environment and the availability of suitable response technologies in cold, icy conditions. The After Action Review for the *M/V Selendang Ayu* incident discussed the following specific R&D Needs (Wood & Associates, 2005):

- **Response Management Systems (SRA 2100) -** improve information sharing, including identification of response equipment and resource availability.
- **Chemical/Physical Modeling (SRA 3200) -** develop methods to determine the transportation and fate of oil in Arctic waters.
- **In and On-water Containment and Recovery (SRA 3400) -** develop measures of containment for application in Arctic conditions.
- **Shoreline Containment and Recovery (SRA 3500) -** develop technology improvements for Arctic shorelines and weather conditions.

T/V Bow Mariner

In February 2004, the *T/V Bow Mariner* crew was engaged in cleaning residual Methyl Tertiary Butyl Ether (MTBE) from a cargo tank while in transit. The MTBE caught fire and exploded and the ship sank about 45 nautical miles east of Virginia. Twenty-one men died in the incident and all the cargo was lost. The vessel was carrying 3,188,711 gallons of ethanol, 192,904 gallons of No. 6 fuel oil, and 48,266 gallons of diesel, which were all released during the incident. An ignition of a fuel/air mixture, either on deck or in the cargo tanks, caused this casualty; the precise source was not determined. The ethanol, which is miscible in water and diesel oil were dispersed rapidly. The fuel oil created an oil slick that required mechanical recovery. Response actions included fishery closures, and mechanical recovery using skimmers; the vessel was not salvaged. Corexit 9527 was tested for dispersants; however, it was not used due to the cold temperatures and the degree of oil weathering.

A significant contributing factor to this casualty was the failure of the operator, Ceres Hellenic Enterprises, Ltd., and the senior officers of the *Bow Mariner*, to properly implement the company and vessel Safety, Quality and Environmental Protection Management System (USCG, 2005). Although specific R&D Needs were not identified, this incident highlighted the need for research in key SRAs:

- **Human Error Factors (SRA 1000) -** study explosion hazards related to tank cleaning operations
- **Human Error Factors (SRA 1000) -** develop manuals for safe tank cleaning procedures.
- **Human Error Factors (SRA 1000) -** develop adequate training on tank cleaning procedures for crews of vessels carrying explosive materials.
- **Human Error Factors (SRA 1000) -** develop adequate training for multicultural crew cohesiveness.
- **In- and On-water Containment and Recovery (SRA 3400) -** study methods of containment and recovery of ethanol and alternative fuels.
- **Dispersants (SRA 3600) -** study the effectiveness of dispersants in cold water and with weathered oil.

M/V Cosco Busan

In November 2007, the container ship *M/V Cosco Busan* spilled 53,569 gallons of heavy fuel oil from its bunker tanks into San Francisco Bay after the vessel struck the San Francisco-Oakland Bay Bridge in thick fog. The source of the incident was not a tanker transporting crude oil as a component of the oil production and transportation system, but rather a non-tank vessel engaged in maritime commerce spilling oil used to fuel the ship. Investigators concluded that the vessel's pilot was impaired from his use of prescription pharmaceuticals, while piloting the container vessel, which rendered him unable to properly use the onboard radar and electronic navigation charts. The USCG Vessel Traffic Service (VTS) failed to warn the pilot that the vessel was headed for the bridge.

The master of the *M/V Cosco Busan* did not implement several procedures found in the company safety management system related to safe vessel operations, which placed the vessel, crew and environment at risk.

The spill oiled about 200 miles of coastline. The near shore location, the type of oil, and proximity to sensitive and valuable coastal resources resulted in a substantial response. Response activities included: deployment of containment boom; mechanical collection and removal; natural attenuation; beach closures due to health and safety concerns with the fuel oil and; and oiled bird capture and cleaning programs.

This incident was an important driver for research needs involving human error, crew fitness, and waterways management because of the potential to prevent this incident and others like it had these needs been addressed. The ISPR for the *M/V Cosco Busan* (USCG, 2008a,b) noted these specific R&D Needs:

- **Human Error Factor (SRA 1000) -** develop protocols to report changes in crew fitness to the USCG, in a timely manner, including any substantive changes in their medical status or medications.
- **Waterways Management (SRA 1300) -** develop technology improvements to improve vessel traffic monitoring and communications.
- **Response Management Systems (SRA 2100) -** develop improvements to information management systems that provide timely and accurate information for the Federal On-scene Coordinator about the extent of the spill.
- **Environmental Impacts and Recovery (SRA 4100) -** develop improvements to aid in effective bird capture techniques and identify priorities and resources needed to provide the most effective wildlife rescue.
- **Environmental Impacts and Recovery (SRA 4100) -** develop a framework to make beach closure and reopening decisions and incorporate those into local government plans (coordinated through the Area Contingency Plan (ACP)).
- **Human Health and Safety (SRA 4300) -** develop protocols needed to close, open or restrict fisheries after a spill that are written into emergency plans and develop expedited tests to check whether impacted fish are a health risk.
- **Sociological and Economic Impacts (SRA 4400) -** evaluate proper use of and methods to monitor the use of social media during and after spills.

7.2 Offshore Drilling Operations

The explosion and collapse of the *Deepwater Horizon* drilling platform resulted in the largest marine oil spill in history and revealed several Research Needs associated with offshore drilling operations.

Deepwater Horizon (DWH) Oil Spill

In April 2010, an estimated 205.8 million gallons of oil began flowing from a subsea well blowout that followed an explosion and collapse of the *Deepwater Horizon* platform (also called the Macondo 252 well) during exploratory drilling. The platform was located approximately 50 miles south of the coast of Louisiana in waters about 5,000 ft. deep. The explosion on the drill rig killed 11 men and injured 17 others. For approximately three months, efforts to stop the flow at the source were unsuccessful until response operations temporarily capped the well on July 15, 2010. The complete well closure occurred on September 18, 2010. The resultant oil spill caused damage to deepwater and nearshore marine and wildlife habitats across the Gulf States and to the Gulf's fishing and tourism industries.

This spill was declared a Spill of National Significance (SONS). Response to the *Deepwater Horizon* spill was diverse and conducted on a larger scale than any previous efforts. Different response mechanisms were deployed depending on the day, the weather conditions, and the amount and location of oiled shoreline. This included: ISB, subsea and surface dispersant use, booming, and skimming. Application of 1.84 million gallons of dispersants, both aerially and sub-sea at the wellhead, was unprecedented, as was the use of controlled ISB (a global record of 411 individual burns were conducted). This spill was the first where dispersants were applied subsea at the wellhead. Existing options failed to satisfy the public expectations, which led to the testing and evaluation of more than 120,000 response technologies through the Alternative Response Technologies Evaluation System (ARTES) Program.

The magnitude and spatial extent of this spill resulted in the collection of a large amount of monitoring and experimental data. A substantial amount of research studying the effects of the spill and the response on the Gulf of Mexico are ongoing. The incident report (USCG, 2011) highlighted the following R&D Needs:

- **Pre-Baseline (SRA 2000)** - ensure minimum standards and consistency for Gulf of Mexico Area Contingency Plans (ACPs).
- **Pre-Baseline (SRA 2000) -** identify Environmentally Sensitive Areas (ESAs).
- **Source Control and Containment (SRA 3100) -** develop improved technology and response protocols for well blowouts.
- **Response Management Systems (SRA 2100) -** develop systems to better meet the needs of oil spill response organizations.
- **Response Management Systems (SRA 2100) -** establish standards and processes for rapid collection, processing, correlation, analysis and distribution of satellite imagery and oil thickness sensors to direct spill response operations with real-time data.

- **Oil Spill Detection and Surveillance (SRA 3300) -** develop improvements for subsea oil detection.
- **Oil Spill Detection and Surveillance (SRA 3300) -** develop and use enhanced SMART monitoring technologies and protocols in offshore environments.
- **Oil Spill Detection and Surveillance (SRA 3300) -** develop technology to determine oil slick thickness.
- **In- and On-water Containment and Recovery (SRA 3400) -** develop improved and more efficient skimmers and mechanical recovery equipment.
- **In- and On-water Containment and Recovery (SRA 3400) -** use a fully operational Common Operating Picture (COP) available during drills, exercises, and actual events.
- **In- and On-water Containment and Recovery (SRA 3400) -** develop protocols for thorough, independent testing and evaluation of response technologies prior to being used on a spill.
- **Dispersants (SRA 3600) -** study the toxicity of dispersants as a function of oil and dispersant types, and different environments.
- **Dispersants (SRA 3600) -** study dispersant efficacy including volumetric limitations of applications.
- **Dispersants (SRA 3600) -** study dispersant efficacy in mitigation of environmental impacts.
- **Dispersants (SRA 3600) -** develop methods and programs to monitor and track large, dispersed oil plumes.
- **Dispersants (SRA 3600) -** conduct a case study analysis of all aspects of dispersant use including environmental effects of dispersants and dispersed oil.
- **Dispersants (SRA 3600) -** study the effectiveness of dispersants under different environmental conditions (e.g., subsea).
- **ISB (SRA 3700) -** study where ISB can be used as a response option and areas where it can be subject to expedited approval.
- **ISB (SRA 3700) -** study the performance of various fire boom designs and improve technologies for water-cooled and reusable booms.
- **Sociological and Economic Impacts (SRA 4400) -** develop outreach programs for, and incorporate state and local emergency managers into, spill preparedness and response.
- **Sociological and Economic Impacts (SRA 4400) -** Spill of National Significance (SONS) doctrine should be adapted to be more inclusive of state, local and tribal governments in a response.

7.3 On-Shore Pipeline Spills

There are more than 300 oil and hazardous liquid spills annually along the more than 199,000 miles of hazardous liquid pipelines in the U.S. according to PHMSA statistics. Three such spills illustrate the types of Research Needs for pipeline spills.

Enbridge Pipeline

In July 2010, an Enbridge Energy Partners LLP pipeline (30-in. diameter) ruptured near Marshall, Michigan and spilled an estimated 843,000 gallons of crude oil produced from bitumen sands, also known as oil sands products (OSP). The rupture released the oil into Talmadge Creek and it then flowed into the Kalamazoo River, a Lake Michigan tributary. Heavy rains at the time of the incident affected spill behavior and transport causing the river to overtop existing dams and carry the OSP downstream contaminating 35 miles of the Kalamazoo River. The rains resulted during a 25-year flood event that also carried the OSP into the adjacent floodplain.

At the height of the response, more than 2,500 people were working along the impacted river and shoreline. Response measures for this spill included: fish advisories, river closure for dredging operations to remove sunken oil and oil in sediments, and deployment of sediment traps for oil that was not removed during dredging. A significant portion of the oil submerged in the river making detection and recovery difficult. Numerous methods were tried to recover the submerged oil because globules continued to rise from the bottom when bottom sediments were disturbed. Identification of submerged oil was determined by manually disturbing the sediments with a pole. Oil sheens would form where there was submerged oil. Vacuums or passive methods removed the oil. Passive methods of recovery in place continued for a long period after the spill.

Research Needs influenced by this spill included submerged oil detection and recovery for large areas, and cleanup methods for OSP in floodplains. Additional research needs identified by the NRDA team included:

- **Pipeline Systems (SRA 1700) -** develop new advanced technology for sensing pipeline leaks that will reduce leak detection false alarms for new construction and existing pipelines.
- **Pipeline Systems (SRA 1700) -** improve and develop in-line inspection (ILI) to locate and size defects in girth welds and for long seam defects including cracks in electric resistance welded pipe (ERW).
- **Chemical and Physical Modeling and Behavior (SRA 3200) -** study the behavior of OSP when spilled into rivers including weathering and interactions with sediments.

- **Oil Spill Detection and Surveillance (SRA 3300) -** improve technology for detection of submerged oil in rivers.
- **Environmental Impacts and Recovery (SRA 4100) -** study the lethal and sublethal impacts of OSP on biota.
- **Environmental Impacts and Recovery (SRA 4100) -** study the impacts of cleanup activity on subtidal and floodplain habitats.
- **Human Health and Safety (SRA 4300) -** study the impacts of air quality on the community and responders from OSP spills.
- **Sociological and Economic Impacts (SRA 4400) -** study the impacts related to lost recreational opportunities from spills.

Yellowstone River Pipeline

On July 1, 2011, a break occurred in a 12 in. pipeline, owned by ExxonMobil Pipeline Company, under the Yellowstone River, 20 miles upstream from Billings, Montana. The ruptured pipeline leaked an estimated 63,000 gallons into the river before the pipeline was closed. USEPA led the response in close coordination with the State of Montana and other federal agencies. EPA's primary concern was protecting people's health and the environment. The river also is known for Yellowstone River cutthroat trout, a Montana fish of concern.

When the Yellowstone River dropped below pre-spill water levels, oil residue was visible in many areas, including some agricultural lands. Farmers were given instructions for crops and livestock. USEPA held ExxonMobil, the responsible party, accountable for assessment, cleanup and restoration. Cleanup crews recovered only about 420 gallons of crude.

As in the case of the Kalamazoo River, the amount of oil spilled was much higher than it might have been due to that lack of coordination and communication among the pipeline operators. In both cases, there was a substantial delay in closing the valves to shut off the flow. In the Yellowstone River incident, it was estimated two-thirds of the spill volume were attributable to the delay. Although there were no specific recommendations for R&D, this spill emphasized the need for:

- **Human Error Factor (SRA 1000) -** better training and coordination for operators.
- **Pipeline Systems (SRA 1700) -** research on methods of inspection of buried pipelines for erosion.
- **Pipeline Systems (SRA 1700) -** improve existing leak detection technology and health monitoring sensors that are miniaturized, automatic, and robust enough to withstand harsh environments.

- **Environmental Impacts and Recovery (SRA 4100) -** research on the potential impacts of OSP on freshwater fisheries.
- **Environmental Impacts and Recovery (SRA 4100) -** research on the potential impacts and restoration of OSP on crops and livestock.

Pegasus Pipeline

ExxonMobil's Pegasus pipeline carries 3,990,000 gallons per day of crude oil a distance of 850 miles from Patoka, Illinois to Nederland, Texas. The spill occurred on March 29, 2013, when the pipeline carrying Canadian Wabasca heavy crude from the Athabasca oil sands ruptured in Mayflower, Arkansas, about 25 miles northwest of Little Rock. A reported 210,000 - 294,000 gallons of crude were spilled. Approximately 3,990,000 gallons of oil mixed with water were recovered by March 31. Twenty-two homes were evacuated. The EPA classified the leak as a major spill.

The crude oil entered a suburban neighborhood through a leak in the 20 in. pipeline, which was buried an average of two feet below ground. The oil flowed into storm drains leading to nearby Lake Conway, used for recreational fishing. First responders, including fire fighters, city employees, county road crews and police built dikes to block culverts and stop the crude from further fouling the lake. ExxonMobil deployed 3,600 feet of containment boom around the lake. By early morning on March 30, there was no more oil spilling from the pipeline.

The EPA and ExxonMobil conducted air quality monitoring. Overall, air emissions in the community were below levels likely to cause health effects to the public. The Arkansas Division of Environmental Quality (ADEQ) closely reviewed the cleanup, continued to monitor the surface water in the affected areas, and posted regular updates. Although reports identified no specific Research Needs, those that were evident from the Mayflower pipeline spill are similar to Research Needs from the Enbridge Kalamazoo OSP spill:

- **Pipeline Systems (SRA 1700) -** improve and develop in-line inspection (ILI) to locate and size defects in girth welds and long seam defects including cracks in electric resistance welded pipe (ERW).
- **Chemical and Physical Modeling and Behavior (SRA 3200) -** research on OSP weathering and interactions with sediments.
- **Environmental Impacts and Recovery (SRA 4100) -** more research on the impacts of cleanup on habitats.
- **Health and Safety (SRA 4300) -** research on air quality monitoring protocols for OSP spills.

7.4 Facility Spills

Severe weather events, most notably hurricanes in the Gulf of Mexico and the East Coast, were responsible for several spills from facilities in the inland areas in recent years.

Hurricanes Katrina and Rita

Gulf of Mexico Hurricanes Katrina and Rita caused multi-state pollution events in 2005. In total, there were over 500 spills resulting from these storms. Storm damage caused above ground storage facilities to spill an estimated 8 million gallons of oil. The largest spill totaled 3.78 million gallons. It came from facilities operated by Bass Enterprises Production Company in Cox Bay, just east of Port Sulphur in Plaquemines Parish, LA. Another Bass Enterprises spill totaling 461,000 gallons occurred near Pointe a la Hache, LA. The second-largest spill, 1,050,000 gallons, was from a broken pipeline owned by Shell Pipeline Co. near Pilot Town, LA. Chevron Oil is believed to have spilled 991,000 gallons near Empire, LA and 53,000 gallons near Port Fourchon, LA, while Venice Energy Services Co. is believed responsible for the discharge of 840,000 gallons near Venice, LA. Shell also was responsible for 13,440 gallons discharged near Nairn, also in Plaquemines.

These incidents indicated a significant need to have more effective response plans for spills caused by natural disasters. In 2005, the National Response Plan (NRP) was revised into the National Response Framework (NRF), which established a single, comprehensive approach to domestic incident management to prevent, prepare for, respond to, and recover from all hazards including terrorist attacks, major natural disasters, and other emergencies.

The response actions during these storms although not specifically identified in reports, indicate the need for R&D in the following areas:

- **Pre-Spill Baseline (SRA 2000) -** research to identify ESA species and other sensitive or important resources near fixed petroleum facilities.
- **Response Management Systems (SRA 2100) -** develop systems that support response actions for multiple spills during natural disasters.
- **In- and On-water Containment and Recovery (SRA 3400) -** identify and pre-place equipment to support facility responses during natural disasters.

Super Storm Sandy

On October 29, 2012, Hurricane Sandy, also known as Super Storm Sandy, made landfall in New Jersey and caused severe damage in the New York and New Jersey metropolitan area. Official estimates indicate that 336,000 gallons of diesel fuel from the Motiva oil tank facility in Woodbridge, N.J spilled into the Arthur Kill, a tidal strait, after the Sandy storm surge lifted a storage tank and it ruptured. The USCG reported that a secondary containment tank caught most of the oil and that the liquid that escaped moved into the Arthur Kill where booms contained the oil. Two hundred responders were on scene to contain the spill. Initially, an acrid stench filled the air. Air samples collected by the USCG at Arthur Kill showed levels within acceptable thresholds within two days. On the adjacent land, a vacuum truck removed a diesel-and-water mixture next to a local park along the Arthur Kill. Although not specifically identified, the response to this type of storm reflected the research needs for:

- **Response Management Systems (SRA 2100) -** ability to rapidly respond to multiple spills during natural disasters.
- **In- and On-water Containment and Recovery (SRA 3400) -** establish pre-placed equipment to respond to onshore facility spills.

7.5 Railroad Spills

Increased oil production of Bakken crude and Canadian Tar Sands along with limitations on pipeline capacity has resulted in a four-fold increase in rail shipments of crude oil between 2010 and 2014. Two derailments illustrate the types of issues that arise with spills from railroad accidents.

Parkers Prairie Train Accident

On March 27, 2013, a mile-long train hauling oil from Canada derailed in western Minnesota and leaked its crude; the leak was the first major spill of the newly developed North American crude. Fourteen of the 94 cars of the Canadian Pacific mixed freight train left the tracks about 150 miles northwest of Minneapolis near the town of Parkers Prairie. The Minnesota Pollution Control Agency reported three tank cars ruptured and leaked an estimated 20,000 to 30,000 gallons. Cold weather made the crude thicker, hindering the ability to recover the oil.

This incident indicates the need for R&D in the following areas:

- **Rail and Truck Transportation (SRA 1600) -** evaluate accident and incident trends to identify ways to minimize the incident rate of leaks, spills, and damage to the environment due to oil spills.
- **Rail and Truck Transportation (SRA 1600) -** evaluate alternative tank car designs and modifications to minimize risk of oil spills during accidents.
- **In and On-water Containment and Recovery (SRA 3400)** - conduct field tests of cleanup techniques and create protocols for various habitats and conditions.

Lac-Mégantic Train Accident

On July 5, 2013, a unit train with 72 cars of Bakken crude oil stopped at Nantes, Quebec. The engineer parked and left the train in accordance with an expected shift change. At approximately 00:56 hours on July 6, 2013, the train started to move down the track. It rolled down the approximately 1.2% grade into the center of the small tourist town of Lac-Mégantic, derailed and the locomotives detached from the rest of the train. Since there were no signals or track circuits, the rail traffic controller had no initial indication of the runaway train. Many of the derailed tank cars full of oil exploded and burned in the heart of the commercial district. The accident killed forty-seven people.

Canada's Transportation Safety Board investigated the incident and determined "the braking was insufficient to hold" the runaway train and that the crude was very volatile. The Board also found the tank cars were mislabeled and the crude was more flammable than originally thought. The deadly accident spurred USDOT's Federal Railroad Administration (FRA), to improve safety standards, specifically for the transport of hazardous materials. "No train or vehicles transporting specified hazardous materials can be left unattended on a mainline track or side track outside a yard or terminal, unless specifically authorized." New safety procedures are now in place in the U.S. to reduce the potential for any future incidents occurring. These procedures include requirements for notification prior to leaving an unattended train and mandatory safety inspections by first responders. FRA (2015) also proposed new regulations regarding rail cars carrying crude oil.

This incident indicates additional Research Needs for trains carrying oil in these SRAs:

- **Human Error Factor (SRA 1000)** - increase training in the areas of communication and safety for trainman and dispatchers.
- **Human Error Factors (SRA 1000)** - develop programs for vessel crews to improve their understanding of automated vessel functions.
- **Railway and Truck Transport (SRA 1600)** - analyze hazards and develop corresponding mitigation methods and technologies for headspace gases in tank cars.
- **Railway and Truck Transport (SRA 1600)** - evaluate and determine minimum crew size requirements for safe operations of unit trains.
- **Human Safety and Health (SRA 4300)** - develop protocols for first responders and railroad workers to improve safety and communications in locations where railroads are carrying hazardous cargos.
- **Human Safety and Health (SRA 4300)** - study the impacts of burning crude oil on first responders and residents.
- **Sociological and Economic Impacts (SRA 4400)** - study the economic impacts of a major train disaster on a small community.

THIS PAGE INTENTIONALLY LEFT BLANK.

8. Current State of Oil Pollution Knowledge

The ICCOPR research and technology planning process involves continually assessing the current state of oil pollution knowledge. ICCOPR and its members continue to monitor and participate in a wide range of studies, workshops, and other events to gain insight into the state of knowledge regarding oil spill prevention, preparedness, response, and impact assessment and restoration. This chapter highlights some of the major sources of information since the 1997 version of the OPRTP was issued.

8.1 National Research Council - Oil Spill Dispersants: Efficacy and Effects

In 2005, the MMS, NOAA, USCG, and API funded the National Research Council (NRC) to convene a committee of experts to review the state of knowledge on the use of dispersants as a response technology for oil spills. They asked NRC to identify the adequacy of existing information and ongoing research regarding the efficacy and effects of dispersants. The study focused on: understanding the limitations imposed by the various methods used in previous studies; recommending steps to better understand the efficacy of dispersant use; and the effect of dispersed oil on freshwater, estuarine, and marine environments. The NRC completed the report well before the *Deepwater Horizon* oil spill and therefore did not envision the extensive use of dispersants during that response.

The NRC Committee emphasized the need to conduct bench-scale and meso-scale testing in order to be able to better control the environmental factors that are present in large-scale field experiments. They specifically recommended:

- Studies to better predict the effectiveness of dispersants for different oil types and environmental conditions;
- Bench-scale experiments to test effectiveness over a wide range of operating conditions;
- Investigations of the kinetics and transformation products of dispersed oil biodegradation at conditions that represent those that follow significant dilution of the dispersed oil plume;
- Toxicity studies to determine the mechanisms of acute and sublethal toxicity to key organisms from exposure to dispersed oil;
- Wave-tank studies that specifically address the chemical treatment of weathered oil emulsions; and
- Studies to quantify the weathering rates and final fate of chemically dispersed oil droplets compared with undispersed oil.

8.2 The Coastal Response Research Center Workshops

The Coastal Response Research Center (CRRC) was established as a partnership between the NOAA OR&R, and the University of New Hampshire (UNH) in 2003. The CRRC's complementary organization is the Center for Spills in the Environment (CSE). CSE receives funding from sources other than NOAA.

The primary purpose of the CRRC and CSE is to bring together the resources of a research-oriented university and the expertise of governmental agencies, NGOs, academia and industry to conduct and oversee basic and applied research, conduct outreach, and encourage strategic partnerships in spill response, assessment and restoration. The CRRC and CSE hosted numerous workshops that brought together national and international oil spill experts to discuss future R&D Needs. The following workshops identified Research Needs that are important to the improvement of oil spill response and the understanding of potential effects:

- Research & Development Priorities: An Oil Spill Workshop (November 2003)
- Research & Development Needs For Making Decisions Regarding Dispersing Oil (September 2005)
- R&D Needs for Addressing the Human Dimensions of Oil Spills (June 2006)
- Submerged Oil Workshop Report (December 2006)
- R&D Priorities: Oil Spill Workshop (March 2009)
- Coordinating R&D on Oil Spill Response In the Wake of *Deepwater Horizon* (July 2011)
- A Forum – Oil Spill Research (January 2012)
- The Future of Dispersant Use in Oil Spill Response Initiative (March 2012)
- Oil Spill Dispersant Research Forum (March 2013)
- Alberta Oil Sands Workshop (April 2013) Washington State Department of Ecology, the Regional Response Team 10 and Pacific States/British Columbia Oil Spill Task Force (April 2013)
- Environmental Disaster Data Management Workshop (September 2014)

Research and Development Priorities: An Oil Spill Workshop (November 2003)

This CRRC workshop provided a foundation for a NOAA R&D strategic plan and a road map for funding decisions for five years. The participants considered Research Needs and then prioritized them in terms of short- and long-term research objectives, cost effectiveness, and applicability to response and restoration actions.

The topics were grouped into themes because many overlapped or were similar:

- Physical Transport Forecasting;
- Oil Weathering: Data Development and Modeling;

- Ecosystem Services: Identification and Valuation;
- Communication: Public and Stakeholder Participation in Response and Restoration;
- Restoration Review;
- Chronic Effects of Oil at Individual and Habitat Levels;
- Methods and Techniques; and
- New Tools for Restoration and Recovery.

Research & Development Needs For Making Decisions Regarding Dispersing Oil (September 2005)

This CRRC workshop used the major topic recommendations from the 2005 NRC study on dispersant efficacy and effects to serve as the basis for the workshop discussion. The NRC report provided recommendations for major research topic areas within six R&D categories:

- chemical effectiveness of dispersant formulations;
- operational effectiveness parameters;
- hydrodynamics and integration of data needed to develop modeling capabilities to predict and evaluate dispersant effectiveness;
- short- and long-term toxicity of dispersants and dispersed oil;
- long-term fate of dispersants and dispersed oil, including biodegradation; and
- development of relevant exposure regimes.

R&D Needs for Addressing the Human Dimensions of Oil Spills (June 2006)

The goal of the CRRC Human Dimensions of Oil Spills Workshop was to bring together a broad spectrum of human dimensions researchers and oil spill practitioners, including industry representatives and regulators, to develop a list of research needs on human dimensions that the Center could use in Request for Proposals (RFPs) and announcements from other funding entities. CRRC specifically designed the workshop to gather holistic perspectives and feedback from all stakeholder groups involved in oil spill response and restoration.

Six research topics were noted as critical components to incorporate into NRDA and other spill response processes. They were:

- Human Use Dimensions;
- Risk Communication;
- Valuing Natural Resources;
- Social Impacts;
- Subsistence;

- Coordination in Response and Restoration; and
- Environmental Ethics.

Submerged Oil Workshop (December 2006)

The overall goal of this CRRC workshop was to identify Research Needs information on submerged oil pertaining to the following response and restoration topics:

- Detection and Monitoring;
- Fate and Transport;
- Containment and Recovery (including Protection of Water Intakes); and
- Effects and Restoration.

R&D Priorities: Oil Spill Workshop (March 2009)

This CRRC workshop focused on areas where significant Research Needs still existed. This was a follow-up to the 2003 CRRC five-year R&D Needs Workshop. Participants were asked to discuss the needs in the areas of:

- **Spill Response During Disasters** - This area addressed issues that are encountered during natural (e.g., earthquakes, hurricanes, floods) or anthropogenic (e.g., accidents) disasters resulting in nearshore and offshore oil spills. Planning and implementation gaps and health and safety issues were the primary focus.

- **Response Technologies** - This research area addressed planning, implementation, technology and effectiveness issues for response (i.e., bioremediation, surface washing agents, solidifiers, sorbents, dispersants, and ISB).

- **Acquisition, Synthesis and Management of Information** - This research topic focused on practices and methodologies for accessing and using remote-sensing data, real-time observational data systems, electronic data collection via field surveys, and geographic information systems (GIS).

- **Human Dimensions** - This research topic addressed the human dimension as part of a response, including: 1) minimizing social impacts and subsequent response activities; 2) developing strategies to address the long-term socioeconomic effects oil spills have on a region's culture and vitality; 3) translating and incorporating social science research, methodologies, and initiatives into individual and collective response plans; and 4) assessing where social science research "fits" into the spill management structure.

- **Ecological Monitoring and Recovery Following Spills** – This research area focused on: 1) understanding long-term ecological recovery to make informed decisions from response to restoration; 2) understanding the ecological factors affecting recovery rates; 3) developing ecological 'metrics' that can be applied by resource managers to develop restoration projects that best compensate for lost resources.

- **Biofuels** – This topic addressed research on first generation biofuel blends in terms of spill response technologies and determination of fate and effects after a spill.

- **Ecological Effects of Oil Spills** – This topic addressed issues around the long-term effects of residual oil in the environment, including the levels and types of adverse effects resulting when oil remains, and the effects of an oil spill that may be magnified by the clean-up technologies.

- **Environmental Forensics** - This topic focused on chemical fingerprinting methods to determine the source and extent of oil resulting from an incident. This information can be important for clean-up, assessment, recovery, monitoring, and associated liability issues.

Coordinating R&D on Oil Spill Response in the Wake of Deepwater Horizon (April 2011)

The CSE organized this workshop to bring together experts from across a broad spectrum of organizations to address the state of future oil spill response research and practices. The overarching goals were to: (1) develop an updated list of Research Needs for response related to dispersant efficacy and effects, spill trajectory modeling, detection of surface and subsurface oil, human dimensions in spill response, seafood safety monitoring and information management; and (2) create a dialogue between researchers and responders in order to ensure translation of research results into practice.

A Forum –Oil Spill Research (January 2012)

The goal of this forum is to encourage dialogue among Principal investigators (PI's) of current research related to oil spill response (e.g., GoMRI, NSF) and industry and government representatives in order to coordinate R&D activities regarding future oil spill response in the wake of the *Deepwater Horizon.*

The objectives of this forum were to review previous and on-going R&D conducted by academic, governmental agencies and industry; present newly funded projects so that everyone is aware of what types of research are being conducted; and evaluate mechanisms for scientific exchange and coordination of oil spill response R&D efforts going forward.

As defined for this forum, oil spill response R&D encompassed any of the following topics:

- Physical, Chemical and Biological Fate and Transport;
- Biological Effects - Resources at Risk;
- Response Technologies;
- Oil Spill Modeling;
- Monitoring and Detection of Surface, Subsurface and Dispersed Oil;
- Human Dimensions and Risk Communication.

The Future of Dispersant Use in Oil Spill Response Initiative (March 2012)

CRRC convened this workshop with the goal of bringing together federal and state representatives, academic scientists, responders, and other stakeholders to discuss the future of dispersant use in spill response in the United States. The overall goals for the workshop were to:

- Build a fact-based consensus on the trade-offs associated with dispersant use;
- Evaluate the current state-of-knowledge on the monitoring, behavior, effects, and fate of dispersants;
- Identify information gaps; and
- Recommend R&D topics to help inform dispersant use in future spill response.

Oil Spill Dispersant Research Forum (March 2013)

Coordination with research, technology, application, and response is needed to optimize dispersant efficacy and effectiveness. After the *Deepwater Horizon* oil spill, there was an increase of research on dispersants and dispersed oil, with a large amount of research coming from the Gulf of Mexico Research Initiative (GoMRI), BSEE, and industry.

This workshop focuses on enhancing communication about dispersant related research and its application, use, and transition to spill response efforts. It was convened with the goal of encouraging, opening, and continuing dialogue among principal investigators (PIs) of research related to dispersant use and response practitioners. The overall objective was to review prior and current research and development (R&D) conducted by academia, government agencies and industry and evaluate mechanisms for scientific exchange and coordination of these efforts. Specific objectives were to:

- Learn about on-going and newly funded R&D on dispersants and dispersed oil (DDO);
- Determine how on-going and new R&D on DDO can improve dispersant use (assuming that dispersants will continue to be a tool in some spill responses);

- Develop mechanisms for information exchange/interaction among researchers, practitioners and public/nongovernmental organizations regarding DDO;
- Explore data needs, tradeoffs, and decisions of practitioners regarding DDO before, during and after spills; and
- Identify potential R&D efforts on DDO that could improve dispersant use during future spills offshore. Other goals were to (1) encourage and continue dialogue on DDO among researchers, spill practitioners and NGO's; and 2) foster mechanisms to enhance public understanding;
- Common themes across breakout groups at the meeting included: enhancing and continuing communication between researchers and responders regarding DDO; increasing public outreach and education; and improving comprehensive and transparent transition of research from laboratory to field application. Modeling is a tool that could act as a potential bridge between laboratory research and field application.

Alberta Oil Sands Workshop (April 2013)

The Washington Department of Ecology contacted the University of New Hampshire's CSE to conduct a workshop for relevant state and Federal agencies on the important issues related to OSP characteristics, transportation and response planning. A similar training was conducted for the State of Maine related to transport of OSP and Bakken crude through that State.

The first day of the workshop was an open forum, which provided information to a broad group of stakeholders from the region. The second day was a working session for response practitioners to focus on issues related to potential OSP spill scenarios. Task groups were given four potential scenarios to test the current understanding of OSP and identify future information and other needs. The breakout groups identified actions that could be taken to improve both near- and longer-term OSP spill response.

Environmental Disaster Data Management Workshop (September 2014)

In the wake of the *Deepwater Horizon* oil spill, the significant body of information, including new research, has highlighted the need for improved coordination of data management. It is common for multiple organizations to collect data that vary significantly in quality, collection methods, access, and other factors that affect use by others. These differences result in limitations for use of the data including comparing results or making inferences.

The Environmental Disasters Data Management (EDDM) Workshop, organized by NOAA's OR&R with assistance from CRRC, was the beginning of a project to foster communication between collectors, managers, and users of with a goal to identify and establish best practices for orderly collection, storage, and retrieval of data. The objectives of the EDDM project are to:

- Engage the community of data users, data managers, and data collectors to foster a culture of applying consistent terms and concepts, data flow, and quality assurance and control;
- Provide oversight in the establishment and integration of foundational, baseline data collected prior to an environmental event;
- Provide best-practice guidance for data and metadata management
- Suggest infrastructure design elements to facilitate quick and efficient search, discovery, and retrieval of data; and
- Define the characteristics of a "gold standard" data management plan for appropriate data sampling, formatting, reliability, and retrievability.

8.3 Department of Energy (DOE) Programs

DOE's ongoing research within the Office of Fossil Energy is focused on the prudent development of domestic oil and gas resources. Onshore research is coordinated with the USEPA and the Department of the Interior (DOI)/US Geological Survey (USGS). The three agencies jointly developed a framework for Federal research that addresses how to safely and prudently develop the Nation's unconventional oil and gas resources. The unique and specific core research competencies of each agency underpin the synergy of this research effort. This multiagency research strategy includes key research questions the agencies will address in a coordinated fashion. These research questions focus on protecting groundwater and air quality, reducing, reusing, and recycling water used in upstream exploration and production operations, reducing the surface and subsurface impacts of oil and gas exploration and production activities, and improve the understanding for the purpose of mitigating induced seismicity.

Offshore research is coordinated with the DOI/Bureau of Safety and Environmental Enforcement (BSEE). Prior to the BP Deepwater Horizon oil spill, DOE's offshore research had been directed at maximizing the value of the Nation's offshore oil and gas resources while protecting the environment. A recommendation of the President's National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling was that DOE should refocus its offshore research activities. In working with the DOI/BSEE Ocean Energy Safety Advisory Committee, DOE refocused its offshore research program on oil spill prevention. DOE's focus has since been on assessment and mitigation of the risk of loss of well control so as to prevent oil spills. Research pathways include: identification of geologic hazards, well control during the drilling and completion process, integrity of the surface facilities and umbilicals, and subsea reliability and automation.

8.4 Ultra-Deepwater Advisory Committee Annual Plan Reviews

The Ultra-Deepwater Advisory Committee (UDAC) was formed in 2007 to advise the Secretary of Energy on the development and implementation of programs related to ultra-deepwater (UDW). The Committee, sunset in 2013, provided recommendations for incorporation into DOE's annual plan of research.

In 2011, the UDAC suggested that, because of the *Deepwater Horizon* accident, there should be projects aimed at placing additional measuring instruments in the well and/or at the wellhead to determine the nature of the well fluids, pressures, and their flow status in real time. They recommended that this work be combined with development of secure methods for transmitting the data to the surface and providing timely interpretation. Analysis of the *Deepwater Horizon* incident indicated that a lack of reliable information hampered control efforts from the initial blowout to the final capping of the well. The UDAC also recommended conducting studies of current subsea containment and capture technologies (hardware), including gap analyses and needs for future technologies with emphasis on subsea capture systems that are independent of surface facilities. Because a number of behavioral factors associated with operations, maintenance, and training contributed to the *Deepwater Horizon* incident, the UDAC recommended research aimed at discovering the fundamental attitudes of rig personnel and associated groups to health and safety issues.

In the 2012 review of the DOE offshore research plan, the UDAC indicated that there was a strong emphasis on the engineering aspects of increasing safety, but little attention was given to the aspects of human behavior regarding safety. However, given the causal factors in the *Deepwater Horizon* incident, research into how to conduct the human aspect of operations safety and how to use advanced decision support and backup systems is not only prudent, but also mandatory.

The UDAC indicated that information is limited regarding methods to prevent and respond to catastrophic events, and mitigate the negative impacts of spills in remote, harsh and sensitive environments. Environmental protection and personnel health and safety working in harsh, unique and sensitive marine habitats, such as Arctic waters and tropical coral reef areas, requires additional focus. To accomplish this, the UDAC recommended that a gap analysis be conducted to catalog and characterize the salient differences between operations in the Gulf of Mexico and those environments encountered in drilling and completion in unique and sensitive marine habitats, such as Arctic waters and tropical coral reef environments, to assess the risks that demand more research.

Finally to further improve safety, the UDAC recommended the present scope of expert (case-based) systems be determined, and then benefits and limitations be identified, as well as other applications (e.g., cementing, completions, wellbore design), that would reduce the risk when operating in deepwater.

8.5 Deepwater Horizon Oil Spill Principal Investigator Conferences

The *Deepwater Horizon* oil spill focused unprecedented attention on the Gulf of Mexico ecosystem. During the response to the *Deepwater Horizon* event, resource managers and researchers from across the country collaborated to conduct science, monitoring, and response activities to understand impacts from the spill. The data and information collected from those efforts have since been used to make progress towards the long-term goal of protecting and restoring public health and natural resources in the Gulf of Mexico.

In 2010 and 2011, the National Science and Technology Council's Joint Subcommittee on Ocean Science and Technology (NSTC JSOST) convened two major workshops in St. Petersburg, Florida of Principal Investigators (PIs) actively involved in research, sampling, and monitoring activities in response to the *Deepwater Horizon* incident. Each of the workshops was an opportunity for PIs to foster new collaborations, compare initial results, interact with federal agencies, and discuss recommendations for longer-term research activities.

> The October 2010 Conference had six breakout groups. Five groups addressed oil/dispersant: fate and extent; impacts and mitigation in the offshore; impacts and mitigation in coastal areas; impacts and mitigation on living marine resources; and impacts and mitigation on human health and socio-economic systems. The sixth group addressed the use of *in situ* and remote sensors, sampling, and systems for assessing the extent, fate, impacts, and mitigation of oil/dispersant.

The follow-on workshop in October 2011 was an opportunity for researchers to present results of studies that were in progress during the first conference in October 2010. The second conference provided a significant amount of information regarding the spill impacts, early recovery, and the scientific efforts to capture that information. Researchers presented numerous potential research needs going forward. As in the initial 2010 conference, the participants identified a series of overall recommendations and observations about gaps and needs for continued research and ways to improve scientific understanding of Gulf of Mexico science issues.

8.6 Deepwater Horizon Incident Specific Preparedness Review

In January 2011, the USCG Commandant chartered the Incident Specific Preparedness Review (ISPR) for the response to the *Deepwater Horizon* oil spill in 2010 to examine the implementation and effectiveness of the preparedness and response to the incident as it related to the National Contingency Plan, Area Contingency Plans, and other oil spill response plans. The report was divided into three main chapters: Planning and Plan Execution, Organization, and Resources and Readiness. The ISRP also provided a list of lessons learned and recommendations.

- **Planning and Preparedness** - There was a general weakness in the USCG's ability to respond to this type of large spill. The problems were the result of budget reductions organizational structure. The agency needs to reassess its readiness programmatically and reinvest to the extent that Marine Environmental Response (MER) is, once again, firmly established as one of the USCG's core competencies.
- **Area Contingency Plans** - The ISPR found these plans to be inadequate for this size of incident. The USCG needs to provide service-wide direction to all Area Committees, develop minimum standards for contingency plans, and establish an oversight, review, and compliance program.
- **Environmentally Sensitive Areas** - In some planning areas, the ESAs were not identified. In some plans where the areas were listed, they were not prioritized. In a few instances, ESAs did have protection strategies for the heavily affected areas. There must be a national planning process that identifies ESAs and ensures that there are trained personnel, equipment, and strategies adequate to protect these resources.
- **Alternative Response Technologies** - The use of two alternative response technologies, dispersants and ISB, proved critical to preventing wholesale impacts to ESAs. This was possible because the spill characteristics, location, and distribution of ESAs were favorable to the use of these technologies. However, important concerns and questions remain about their impacts on the environment, and more research is necessary before bringing them into the mainstream of spill response options. The use of dispersants during the *Deepwater Horizon* incident identified a need for a thorough review of this response option, its efficacy in minimizing environmental impacts, its overall effect on the environment, and conditions under which they are most effective. Dispersant protocols and authorization procedures should be established and articulated in ACPs. The National Response Team should require that all RRTs establish ISB guidelines as a viable response option in their area of responsibility, consistent with public health and safety issues.
- **Effective Daily Recovery Capacity (EDRC)** - EDRC is the planning standard used to estimate the rate at which mechanical means (e.g., skimmers) can recover an amount of oil and rate capabilities of oil spill removal organizations (OSROs). Revised EDRC requirements could stimulate OSROs to invest in response research and development, with the goal of developing skimmers and other recovery equipment that are more efficient.

- **Funding** - Many of the recommendations provided in the report require additional or new funding. The *Deepwater Horizon* incident showed the response community and the public that a "business as usual" approach to funding would not work.
- **National Response Framework (NRF)** - The USCG should fully implement its policy on connectivity with the NRF, including an expanded outreach program to state and local emergency managers through sector participation with Local Emergency Planning Committees, and District participation with Regional Interagency Steering Committees.
- **Crisis Leadership** - The *Deepwater Horizon* incident placed individuals into crisis management roles, and not all were able to demonstrate the required leadership. The National Incident Command concept worked very well during this incident, and it provides a model for selecting individuals with the necessary crisis management skills to lead response efforts and to manage effectively future national incidents.
- **Lessons Learned** - The USCG needs to formally address lessons learned, institutionalize them through programmatic changes, and in some cases, through cultural changes.

8.7 National Commission on BP Deepwater Horizon - Final Report

In January 2011, the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (Commission) issued their Report to the President – Deepwater: The Gulf Oil Disaster and the Future of Offshore Drilling. The Commission's complete recommendations in the report reflect the government's sweeping sovereign authority as owner of the seabed and water column and, as the regulator of activities there, with the overriding responsibility to manage and protect the valuable resources of the outer continental shelf (OCS) on behalf of current and future generations. The Commission's report grouped recommendations in nine distinct areas:

- Improving the safety of offshore operations through greater government oversight and control including a new regulatory organizational structure;
- Improving the safety of offshore operations by industry through greater emphasis on a more risk based approach to operations and safety;
- Safeguarding the environment;
- Strengthening oil spill response, planning, and capacity;
- Advancing well-containment capabilities;
- Overcoming the impacts of the *Deepwater Horizon* spill and restoring the Gulf;
- Ensuring financial responsibility;
- Promoting Congressional engagement to ensure responsible offshore drilling; and

- Developing approaches for frontier regions to incorporate lessons learned during the *Deepwater Horizon* oil spill.

Within each of the major categories, the Commission had additional specific actions and recommendations to improve offshore drilling prevention, preparedness, response and environmental protection and restoration.

The Commission Staff Working Paper No. 7, "Response/Clean-up Technology Research & Development and the BP Deepwater Horizon Oil Spill," documented the state of research and development by the private sector and federal government specific to containment and well-control technology. The paper was provided to the full Commission for consideration as it deliberated it report to the President. The paper discussed three basic questions:

- Does the private sector invest less than the socially optimal amount in response/cleanup technology?
- Do federal agencies lack adequate long-term funding to maintain response/cleanup preparedness?
- Can the federal government and industry create a set of incentive for private companies and government agencies that would optimize levels of investment in response/cleanup technology?

The paper concluded that there was a response R&D gap. The paper suggested that the National Commission consider:

- Recommending language in OPA 90 to guarantee the full oil spill research authorization provided in the Act as originally intended.
- Recommending OPA 90 be amended to guarantee sustained and additional funding for Ohmsett.
- Recommending ways to stimulate the cleanup technology market and incentivize related R&D,
- Recommending that the EDRC regulations be revised to give an incentive for response companies to employ the most efficient recovery equipment.
- Recommending that EPA streamline the permitting process for open-water testing and that EPA loosen its oiled-water discharge requirements for technology testing purposes.

8.8 Public Meetings, Letters, and Reports Submitted to ICCOPR

As part of the R&T planning process, ICCOPR held three public meetings in 2010 to solicit input on future oil pollution research needs. ICOCPR advertised the public meetings in the Federal Register and conducted them on the West, East, and Gulf Coasts to obtain different regional interests and perspectives.

In addition to the public meetings, ICCOPR also received letters from the Pacific States/British Columbia Oil Spill Task Force, the U.S. Arctic Research Commission, and the Marine Mammal Commission and a report entitled "Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in the Gulf of Mexico: A Statement of Research Needs."

8.9 National Research Council: Responding to Oil Spills in the U.S. Arctic Marine Environment

A group of organizations requested that the National Research Council of the National Academy of Sciences conduct a study of the current capabilities to respond to oil spills in the Arctic. ICCOPR sponsors included the USCG, BSEE, BOEM, NOAA, and USARC. Other sponsors included API, Marine Mammal Commission, and OSRI. The report had four main sections: 1) Environmental Conditions and Natural Resources in the U.S. Arctic; 2) Arctic Oil Spill Response Research; 3) Operations, Logistics, and Coordination in an Arctic Oil Spill; and, 4) Strategies for Response and Mitigation. Each section described the current state of knowledge or capabilities of the U.S. response organizations and made recommendations for an effective prevention, preparedness, and response system.

NRC released the report after ICCOPR had completed the Research Needs Identification Process (see section 6.1) and was in the Needs Prioritization Process (see section 6.2). The R&T Plan Workgroup reviewed the NRC report and determined that the recommendations were consistent with the Research Needs already under consideration. The Workgroup used the NRC recommendations as a factor in selecting priority Research Needs.

8.10 National Petroleum Council: Arctic Potential – Realizing the Promise of U.S. Arctic Oil and Gas Resources

In 2013, the Secretary of Energy commissioned the National Petroleum Council (NPC) to conduct a comprehensive study considering the research and technology opportunities to enable prudent development of U.S. Arctic oil and gas resources. The study included an in-depth assessment of available offshore oil and gas technology, ongoing research, and research opportunities, in six areas:

- Ice characterization
- Oil and gas exploration and development
- Logistics and infrastructure
- Oil spill prevention and response
- Ecology, and
- Human environment.

The report includes extensive information on the state of knowledge on Arctic technologies and operations, spill prevention and response capabilities, and the ecological and human environment. The NPC issued the Executive Summary of the report in March 2015 after ICCOPR had completed the prioritization process and was in the final stages of developing the text of this OPRTP. As such, the NPC report was issued too late for ICCOPR to consider it in developing this version of the Plan. However, ICCOPR will continue to review the NPC report and use it as a source of information.

8.11 Industry Reports

The oil and gas industry convened the Joint Industry Oil Spill Preparedness and Response (OSPR) Task Force (JITF) in June 2010 to evaluate procedures and lessons learned during the *Deepwater Horizon* oil spill response. The initial focus of the JITF was to identify potential opportunities for improvement to oil spill response systems in the areas of planning and coordination, optimization of each response tool, R&D, technology advancement, and training/education of all parties preparing for or responding to an oil spill. The JITF spent several months developing and prioritizing project plans to address each preliminary recommendation, and subsequently received approval and Industry funding for a multi-year work program. The JITF divided its recommendations into seven categories, or work streams:

- Planning;
- Dispersants;
- Shoreline protection and cleanup;
- Oil sensing and tracking;
- *In-situ* burning;
- Mechanical recovery; and
- Alternative technologies.

Nine oil and gas companies established the Arctic Oil Spill Response Technology Oil Joint Industry Programme (JIP) to further build on existing research and improve the technologies and methodologies for Arctic oil spill response. The goal of the JIP was to advance Arctic oil spill response strategies, improve equipment and increase understanding of potential impacts of oil on the Arctic marine environment. There were seven key areas of research addressed by the JIP specifically for the Arctic:

- Dispersants;
- Environmental effects;
- Trajectory modeling;
- Remote sensing;

- Mechanical recovery;
- *In-situ burning*; and
- Field research.

8.12 Prince William Sound Oil Spill Recovery Institute (OSRI) Research Plan 2011-2015 (February 2010)

The Prince William Sound (PWS) Oil Spill Recovery Institute (OSRI) was authorized in 1990 by the United States Congress to "identify and develop the best available techniques, equipment, and materials for dealing with oil spills in the Arctic and sub-Arctic marine environments" (Title V, Section 5001, Oil Pollution Act of 1990). OPA 90 amendments in 1996 and 2005expanded the area of emphasis and extended the life of OSRI programs until one year after the completion of oil exploration and development efforts in Alaska.

OSRI sponsors research programs on physical oceanography and meteorology designed to improve the ability to forecast weather and ocean conditions. OSRI works with a wide array of industry and agency organizations to sponsor technological improvements for oil spill response. This includes contributing to the testing of new skimmer technologies, sensitivity index maps, and sponsoring workshops to identify best practices and research needs. It supports K-12 classroom programs and recently worked to include more technology in the education programs. With the increased desire by industry to develop offshore regions of the Arctic, there is greater emphasis on improving technologies for oil spill response in ice-laden waters.

OSRI's 2011-2015 Research Plan outlines the priority research areas that it will be funding:

- Interdisciplinary approaches to understanding the fate and effects of an oil spill in the Arctic and the recovery of that oil;
- Development of response tools to assist responders to mitigate the impact of spills in the Arctic; and
- Communication and education of the public on the issues related to oil spills in the Arctic.

9. Oil Spill Research and Technology Priorities

ICCOPR selected 150 priority oil pollution Research Needs to address the 25 SRAs and SRA subcategories using the deliberative process described in Chapter 6. These priorities represent the federal opinion on where federal research programs should focus in order to make the most progress to addressing the overall Research Needs. Each federal agency should consider these priorities as they make their research investments. ICCOPR encourages non-federal research programs to use these priorities as well. ICCOPR will track progress toward addressing these priorities during the next planning cycle and establish a new set of priorities at that time.

ICCOPR organized the priority Research Needs by the four major Classes of research: Prevention, Preparedness, Response, and Injury Assessment and Restoration (Figure 9-1)

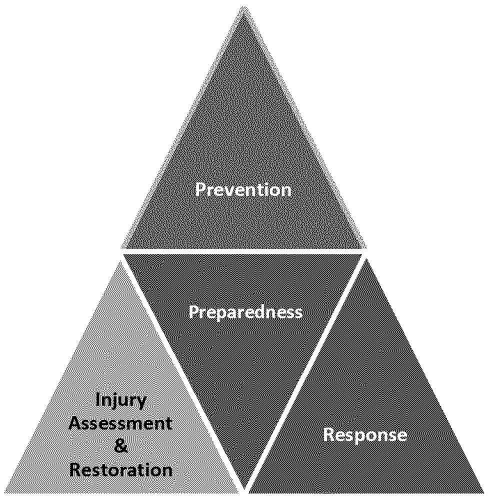


Figure 9-1 - The Oil Spill Research Categorization Framework

As discussed in Section 4.1, this framework embodies the concept that the research in each Class can inform and support the research from other classes; and that the Preparedness class plays a central role in supporting them all. Member organizations may conduct or support research in a single Class or multiple Classes depending on their specific mission, regulatory responsibilities, and/or expertise.

Table 9-1 lists the Classes and the SRAs they encompass. The following sections present the top priority Research Needs by Class and SRA or SRA subcategory. The order of the three priorities listed within an SRA or SRA subcategory is not indicative of their relative importance. All three are of equal importance. The Classes are:

Prevention Class - Research that supports the development of practices and technologies designed to reduce the likelihood of releases or minimize the volume of oil released into the environment.

Preparedness Class - Research that determines baseline conditions or supports the activities, programs, and systems typically developed prior to an oil spill to improve the planning, decision-making, and management processes needed for responding to and recovering from oil spills.

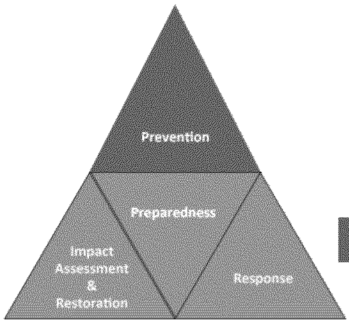
Response Class - Research that supports techniques and technologies that address the immediate and short-term effects of an oil spill and encompasses all activities involved in containing, cleaning up and treating oil in order to: 1) maintain safety of human life; 2) stabilize a situation to preclude it from worsening, and 3) minimize adverse environmental and socioeconomic effects.

Injury Assessment and Restoration Class - Research that involves the collection and analysis of information to evaluate the nature and extent of environmental, human health, and socioeconomic injuries resulting from an incident, and determine and refine the restoration actions needed to bring injured natural resources and services back to pre-spill conditions and make the environment and public whole after interim losses.

Table 9-1 Standing Research Areas (SRAs) by Research Class

Prevention	Preparedness	Response	Injury Assessment & Restoration
• Human Error Factors • Offshore Facility and Systems • Onshore Facilities and Systems • Waterways Management • Vessel Design • Drilling • Rail & Truck Transportation • Pipeline Systems	• Pre-spill Baseline Studies • Response Management Systems	• Structural Damage Assessment and Salvage • At Source Control and Containment • Chemical and Physical Behavior Modeling • Oil Spill Detection and Surveillance • In- and On-water Containment and Recovery • Shore Containment and Recovery • Dispersants • In-situ Burning • Alternative Countermeasures • Oily and Oil Waste Disposal • Bioremediation	• Environmental Impacts and Ecosystem Recovery • Environmental Restoration Methods and Technologies • Human Safety and Health • Sociological and Economic Impacts

9.1 Prevention Priority Research Needs



PREVENTION

9.1.1 Human Error Factors Priorities (Section 4.3.1.1)

This SRA focuses on how human performance and factors contribute to accidents in the oil production/transportation system. It includes the development of advanced methods and systems for training operational personnel, basic research on operating personnel performance in preventing oil spills (safe navigation on vessels, proper oil transfer practices, analysis/evaluation of equipment monitoring systems, decision-making processes), and the development of methods and technologies to evaluate the ability and knowledge of operating personnel in performing their duties. This may extend to evaluation of the overall management culture and its ability to foster the appropriate organizational safety, preparedness and response operating environment.

The priorities selected focus on improving the performance of individuals to reduce potential spills through better technology and improved training methods. ICCOPR selected Research Needs that emphasized development of innovative training methods by using simulations and gaming. At the operational level, improvements in instrumentation and data interpretation technology are essential to allow better decisions to be made on vessels, in ports, and on railway and pipeline transportation systems.

- Improve performance and decision-making by developing innovative training methods including readiness evaluations, gaming and simulators.
- Conduct research to determine current level of expertise for operators within modern transportation systems including marine, rail, truck, and pipeline.
- Improve and develop sensors; instrumentation; command electronics; and advanced data interpretation technologies and alert systems, including data analysis and expert systems to enhance decision-making capabilities.

9.1.2 Offshore Facilities and Systems Priorities (Section 4.3.1.2)

This SRA includes: offshore exploration and development wells, platforms, and well control systems; the methods, techniques, and equipment for system reliability inspections; systems to detect, prevent, and mitigate oil and gas discharges; and equipment to regain control of a well blowout or any other accidental discharge. It also includes transfer equipment, storage units, and piping used to transfer oil within the offshore system and connect the system to transfer pipelines. This technology is relevant for the multiple operating environments of exploration and production activities (e.g., Arctic, shallow, deep and ultra-deep waters).

One of the selected priorities acknowledges the special conditions that occur in the Arctic. Another priority recognizes the need to address material integrity in deepwater, the Arctic and other frontier drilling locations.

☐ Evaluate corrosion and corrosion mitigation processes at the splash zone for offshore platforms.
☐ Study effects of ice forces, scour and gouging with respect to prevention of oil spills from offshore facilities.
☐ Conduct studies related to the longevity and integrity of metallic materials used under extreme conditions in relation to new surface treatments and alloys.

9.1.3 Onshore Facilities and Systems Priorities (Section 4.3.1.3)

This SRA includes designs, techniques, operational procedures and equipment for fixed onshore facilities including wells. It covers inspections and systems to detect, prevent, and mitigate oil and gas discharges from the facilities and their systems, including transfer equipment, storage, and piping.

The priorities for this SRA emphasize the need to improve the integrity and operations of onshore facilities. As in other SRAs, the priorities for Onshore Facilities recognize the need to address the effects of emerging crude and Arctic environments on facility infrastructure. There are two subcategories under this SRA: 1) Tank and Piping Inspection, Operations, Design, and Data; and, 2) Emerging Issues.

TANK AND PIPING INSPECTION, OPERATIONS, DESIGN, AND DATA
☐ Analyze upstream and/or downstream causes and magnitude of discharges from tanks, appurtenances, and associated piping.
☐ Develop improved methods and protocols used to determine the imperviousness of secondary containment structures.
☐ Evaluate the efficacy of sorbent and similar technologies used as oil spill control measures for storm water filtration and secondary containment shut-off drains.

EMERGING ISSUES
☐ Identify the effects of an aging oil storage infrastructure (tanks, appurtenances, and piping systems) and develop methodologies/protocols to predict/minimize failures.
☐ Assess the effects of emerging crude oils and alternative fuels on tanks, appurtenances and piping.
☐ Assess the effects of Arctic and cold weather environments on the operation and maintenance of tanks, appurtenances, and associated piping.

9.1.4 Waterways Management Priorities (Section 4.3.1.4)

This SRA includes methods, equipment, and integrated systems designed to improve navigation at sea and in ports, rivers, and inland waterways. It includes on-board navigation systems, such as integrated navigation and bridge systems and collision avoidance systems. It also includes systems external to the vessel, such as vessel traffic and tracking systems, navigational aids and piloting systems, as well as includes general research into navigation risks, the effects of navigational safety programs, and the development of decision support tools for waterways management efforts. This SRA includes development of navigational channel maintenance programs and analysis of voyage pre-planning processes.

The priorities selected recognize the special nature of operations and navigation in ice-infested waters of the Arctic. They also focus on the need to improve technology on ships and in ports for traffic control.

☐ Improve navigation through enhanced piloting systems, electronic charts and information systems.
☐ Improve systems and protocols needed for traffic control in ports.
☐ Improve Arctic waterways management/vessel accident prevention, including improvements in (a) Arctic communications, (b) emergency response paradigms for vessel accidents (e.g., vessel foundering), (c) ice piloting requirements/qualifications, (d) Arctic weather, and (e) ice forecasting.

9.1.5 Vessel Design Priorities (Section 4.3.1.5)

This SRA includes the development, physical and numerical modeling, and testing of advanced tanker and barge designs to make these vessels less susceptible to damage and less likely to spill their cargoes into the waterways if an accidental grounding, collision or structural failure occurs. This SRA also includes research on non-tank vessel designs (e.g., double-hulled fuel and lube oil tanks) to minimize the possibility of spillage from collisions, allisions, and groundings.

The selection of priorities recognizes the significant progress made because of the double hull tanker design mandated by OPA '90. The priorities in this SRA emphasize the design of vessels for survivability during accidents and the tools and models necessary to assess the effectiveness of ship structures to estimate spill potential. ICCOPR recognizes the need for design improvements for operating in the extreme environments of the Arctic.

- Develop designs and methods to improve survivability of ships and structures in damaged condition.
- Develop improved analytical tools (procedures, computer models, and software) to evaluate performance of structures in collisions, allisions, and groundings, so that estimates of damage extent and loss of oil-tight boundaries are available.
- Develop improved designs and analytical tools (procedures, computer models, and software) for design and operation of ships and marine structures in extreme environments.

9.1.6 Drilling Priorities (Section 4.3.1.6)

This SRA focuses on: the design, construction, and placement of wells (deepwater and ultra-deepwater, and onshore); materials, sensors, and systems needed for offshore drilling and production platforms, and well heads/risers; and techniques and equipment for well and facility monitoring and inspection under extreme pressure and temperature environments. Also included are efforts aimed at understanding the chemical and physical characteristics for the full range of petroleum oils under varying conditions of pressure and temperature; predicting their phase/state, behavior and their physical interaction with other materials in the environment (e.g., rock and sediments); and their impact on engineered systems. Example issues include: early kick detection; systems for communicating and responding to changes in downhole parameters; strategies and methods for training operational personnel on the use of advanced technology; systems to detect and prevent oil and gas discharges; and well-head systems and equipment to control wild wells and cap well blowouts.

ICCOPR again recognizes the need to prioritize research that focuses on operational differences in the Arctic. Other research priorities focus on improving drilling systems and the knowledge of complex reservoir conditions to better assess potential incidents related to stratigraphy and hydrocarbon pathways. There are two subcategories to this SRA: Deepwater Drilling and Technology and Reservoir Characterization.

DEEPWATER DRILLING AND TECHNOLOGY
☐ Evaluate subsea blowout preventer control pod batteries including assessments of battery design, life expectancy, performance, and reliability with respect to different manufacturers.
☐ Conduct a gap analysis on current managed pressure drilling (MPD) techniques to identify future critical needs.
☐ Study the interaction and potential for failure at the interface of each system (formation - cement - instrumentation) and develop advanced downhole tools to assess the integrity of the system *in situ*.
RESERVOIR CHARACTERIZATION
☐ Conduct research, including improved modeling, on the conditions (e.g., *in-situ* stress, sediment rheology, fluid pressure, flow rate, and blowout duration) where hydrocarbon pathways to the sea floor are established through hydraulic fractures and reactivated natural faults.
☐ Characterize reservoirs to identify geologic conditions, such as bounding strata weaknesses that need special engineering considerations to ensure hydrocarbon containment.
☐ Characterize reservoir conditions associated with offshore Arctic oil and gas provinces to identify potential issues in areas of offshore clathrates, sea ice, and other effects.

9.1.7 Rail and Truck Transportation Priorities (Section 4.3.1.7)

This SRA includes the development and testing of rail and truck transport system designs, operations, and infrastructure to make oil tanks less susceptible to damage and loss of cargo during normal operations, train accidents and derailments, or truck accidents. This SRA includes evaluation of vehicle designs, construction materials, spill prevention devices, and loading/unloading systems and equipment. It also includes evaluations of: the physical and chemical characteristics and behavior of the crude oils being shipped, the effects of those characteristics on the tanks during operations and under accident conditions, and systems to control these characteristics. This SRA also includes evaluations of safety systems and processes to: manage the movement and composition of trains and trucks carrying crude oil, prevent accidents and derailments, select preferred shipping routes, and respond safely to an oil spill emergency.

The selection of priorities under this SRA recognizes the increased volume of crude oil transported by rail and truck in response to the energy renaissance in the U.S. and

Canada. ICCOPR also recognizes the unique characteristics of the crude oils transported by rail and trucks and the hazards they pose under accident conditions.

- Analyze hazards and develop corresponding mitigation methods/technologies for head space gases in tank cars.
- Evaluate accident and incident trends to identify ways to minimize the incident rate of leaks, spills, and damage to the environment due to oil spills.
- Evaluate alternative designs and modifications to minimize risk of oil spills during accidents.

9.1.8 Pipeline Systems Priorities (4.3.1.8)

This SRA includes the development, operation, monitoring, and inspection of offshore and onshore pipeline systems used to transport oil between facilities. It covers the pipeline system design, procedures, and equipment for pipeline operations and inspection protocols to prevent, detect, and mitigate oil discharges. Pipeline research under this SRA also includes technologies to prevent (detection/characterization and repair of anomalies before failure) and detect failures, as well as monitor/control systems that can rapidly isolate and shut down operations in order to minimize spillage when failures occur.

ICCOPR in the selection of priorities recognized the need for better detection technology to prevent incidents and protect human health. In the area of ensuring pipeline integrity, ICCOPR recognized the need to develop technology that will detect potential anomalies and failures in pipeline materials. There are two subcategories for this SRA: Materials and Integrity.

MATERIALS

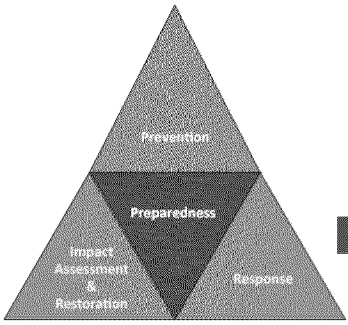
- Develop new advanced technology for sensing pipeline leaks that will reduce leak detection false alarms for new construction and existing pipelines.
- Improve existing leak detection technology and health monitoring sensors so that they are miniaturized, automatic, robust and withstand harsh environments.
- Evaluate the performance, reliability and failure mechanisms of the use of composites technology for pipelines.

INTEGRITY

- Develop technology that detects the presence, location and separation between multiple utilities (underground, through various soil conditions) in a common corridor.

- Improve and develop in-line inspection (ILI) to locate and size defects in girth welds and long seam defects including cracks in electric resistance welded (ERW) pipe.
- Assess the remaining integrity of pipelines that have multiple different anomalies in proximity.

9.2 Preparedness Priority Research Needs



PREPAREDNESS

9.2.1 Pre-spill Baseline Studies Priorities (4.3.2.1)

This SRA includes research to characterize and analyze baseline data on the natural environment, human health, and socio-economic characteristics in areas at risk for oil spills. Research includes risk assessments conducted in areas involved in the oil production and transportation systems to identify locations most at risk from pollution events and therefore priority candidates for baseline studies. Baseline information and studies may include: location and population data on species and their habitats, especially ecologically sensitive species; the epidemiology/human health characteristics of people in potential impact areas; and potential community and economic impacts in these areas (e.g., tourism, commercial/recreational fishing, and seafood industry).

ICCOPR divided this SRA into three subcategories: Habitat and Species Baselines; Oceanographic and Geological Baselines; and Environmental Baseline Planning. In the area of habitat and species planning, there is an emphasis on the need to understand more about important Arctic species, intertidal habitats and species that are often impacted by oil spills, and the deepwater and ultra-deepwater habitats and microbiological assemblages (about which little is known). Some of these environments are or soon will be subject to drilling operations (e.g., Arctic, ultra-deepwater). ICCOPR also identified research needs related to understanding currents and coastal processes in areas where oil and gas extraction occurs to aid in future oil spill response or coastal protection should an incident occur. Research on the amount of variability that exists in baseline data is extremely important in order to document change, identify potential Natural Resource Damages, and establish restoration goals.

HABITATS AND SPECIES BASELINES
□ Study ecological structure and population of key Arctic indicator species and protected species (including those with subsistence and ecosystem importance) particularly in areas that are likely to be explored/developed for oil and gas extraction in the near to mid- term.

- Study and synthesize existing information for intertidal habitats (i.e., sand beaches, rocky and cobble habitats) regarding productivity, species diversity, community structure, and the effects of oil on these parameters, including recovery time, with consideration for regional variation.
- Study ecological structure and population of key indicator and protected species in deepwater and ultra-deepwater (including those with subsistence and ecosystem importance), particularly in areas that are likely to be explored/developed for oil and gas extraction in the near to mid-term.
OCEANOGRAPHIC AND GEOLOGICAL BASELINES
- Conduct a series of large-scale Arctic studies of oceanographic exchanges, shelf-basin exchanges via wind and eddies, coastal boundaries, under-ice river plumes, and sea-ice boundaries to better inform pre- and post-spill modeling and response.
- Develop a better understanding of coastal processes unique to the Gulf of Mexico (i.e., changing shorelines due to erosion, deposition from the Mississippi River) to help inform protection and recovery strategies for oil spills.
- Develop methodologies for using baseline flow characteristic data (such as tidal energy mapping and other energy sources) to support shallow water inlet protection strategies during oil spills.
ENVIRONMENTAL BASELINE PLANNING
- Develop models of background variability relative to habitat and species data in various environments where oil is transported or extracted so that the impacts from oil or other stressor(s) can be delineated from those of natural variation.
- Evaluate the adequacy of existing ecosystem-based scientific studies for legal defense of Natural Resource Damage Assessment (NRDA) injury assessments for Outer Continental Shelf areas that are currently in production or likely to be explored/developed.
- Conduct baseline studies of microbial communities in a variety of areas where oil is transported or extracted (e.g., Great Lakes, rivers, ports, offshore) and their potential for hydrocarbon degradation in the event of a spill.

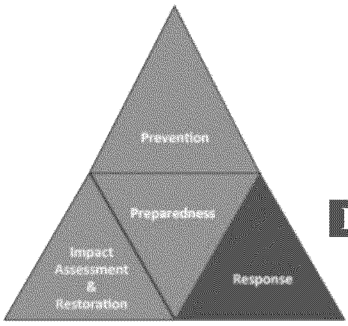
9.2.2 Response Management Systems Priorities (Section 4.3.2.2)

This SRA includes analysis and development of systems to manage how data and information are collected, analyzed, documented, and shared between and among, the planning/preparedness and response communities, the Incident Command System (ICS), and the public. These systems are used to integrate diverse sets of narrative, graphic, and video information and many sets and types of raw and analyzed data. Examples of oil spill information systems include: ICS forms; computer systems; data management software and databases; Geographic Information Systems (GIS); routing, spill and incident management tracking systems; electronic mail and web content; documents, photographs, and video management and archiving systems; communication systems; public information messages and protocols; and graphical displays.

ICCOPR priorities under this SRA recognize the need to upgrade information management systems, develop more rapid methods of incorporating data prior to and during a spill, and improve spill response planning tools. Improved pre-spill planning, development of information management tools, and incorporation of baseline data from current oil and gas extraction areas and potential frontier areas will greatly enhance response should an incident occur.

- Develop techniques and/or software for automatically translating data collected from different sources into common, usable formats.
- Develop spill planning and response tools based on gap analysis of the availability of countermeasures in different Arctic locations and seasons.
- Develop improved information systems for decision-making, including the use of data from coastal mapping, baseline data, and other data related to the environmental effects of oil discharges and cleanup technologies.

9.3 Response Priority Research Needs



RESPONSE

9.3.1 Structural Damage Assessment and Salvage Priorities (Section 4.3.3.1)

This SRA includes the development of methodologies and equipment to assess the extent of damage to a stricken vessel caused by collision, allision, grounding, or improper hull stresses during cargo transfers or explosion. This area also includes development of methods and technology to graphically present the implications of various measures that can be implemented to stabilize the vessel's condition, reduce the potential for further pollution, and allow it to be moved safely for repairs or disposal.

The priorities in this SRA include the need to improve technology to determine the oil and water interface in tanks and develop remote vehicles capable of assessing external integrity of vessel hulls. Another important priority is to evaluate existing wrecks that have the potential to leak petroleum products into marine water.

- Study methods for remotely and rapidly determining whether a cargo tank contains sea water and the extent of the water bottom (height of the oil/water interface from the bottom of the tank).
- Develop technologies and techniques to better determine the presence of oil and the probability of its release from specific sunken vessels.
- Develop improved use of remotely operated vehicles (ROVs) and emerging technologies for underwater assessment of vessel and marine structure integrity.

9.3.2 At-Source Control and Containment Priorities (Section 4.3.3.2)

This SRA includes the development of methods, systems, and equipment for containing and recovering the oil at or from the source and for mitigating oil flow from a damaged vessel, onshore/offshore pipeline, and an exploration or production platform, temporarily abandoned (plugged) well, or well head once the spill has begun. Such technologies include well-head capping systems, remotely operated vehicles (ROVs) for subsea containment activities, and patching, plugging and sealing systems. This technology is applicable to all geographic/environmental areas (Arctic, terrestrial, water surface, subsurface shallow, and deep and ultra-deep water).

ICCOPR selected priorities that reflect the difficulties in containing the well during the *Deepwater Horizon* oil spill. The priorities also reflect an anticipated need to provide at source containment in more extreme environments.

☐ Study the range of failure states and flow rates for which subsea containment may be required.
☐ Develop subsea containment equipment for integration into spill response operations, including relevant procedures and standards for training personnel.
☐ Determine how extreme environmental conditions affect at-source containment and control (including Arctic, ultra-deep and other extreme conditions).

9.3.3 Chemical and Physical Modeling and Behavior Priorities (4.3.3.3)

This SRA includes laboratory and theoretical research and field studies aimed at understanding the behavior and characteristics of the full range of petroleum oils including: behavior and transport in the environment, partitioning of hydrocarbon constituents, and physical interaction with other materials in the environment (rock, sediments, and ice). It includes studies of oil behavior and changes throughout the water column from deepwater blowouts. There is particular interest in non-conventional oils such as those produced in the Bakken and Canadian Tars sands (diluted bitumen (dilbit) and synthetic bitumen (synbit)). It also includes the development and verification of numerical models to predict the surface and subsurface movement and weathering (i.e., spreading, evaporation, dispersion, and dissolution) of oil spills. This SRA also includes methodologies to provide accurate model input data to verify model outputs. This SRA includes development of user-friendly programs to enhance contingency planning and to serve as training aides for spill response teams. Models should be available for various spill scenarios at specific locations for different tidal, current, and weather conditions to pre-plan potential boom deployment strategies and estimate response resource needs.

ICCOPR recognized the importance of addressing research needs related to understanding how oil behaves under differing conditions in both fresh and saltwater, and developing models to use during oil spills. ICCOPR specifically identified priority Research Needs to improve the understanding of how oil behaves in the Arctic and how new emerging oils such as oil sands products and Bakken crude oils behave in the environment. There are five subcategories for this SRA: 1) Arctic Behavior and

Modeling; 2) Oil Behavior Models; 3) Transport Models; 4) Oceanographic Models; and, 5) Emerging Crudes.

ARCTIC BEHAVIOR AND MODELING
☐ Develop improved modeling tools and trajectory models in order to predict spreading of oil in different weather and ice conditions in the Arctic.
☐ Study the fate of oil in Arctic conditions; including open water, ice infested water and oil trapped in ice, particularly as it relates to the effectiveness of spill response countermeasures and the potential for ecosystem exposure.
☐ Study Arctic-based indigenous microbial populations in the water column and benthic sediment, and define rates of microbial processes to determine the role such communities have in the oil weathering process.
OIL BEHAVIOR MODELS
☐ Study the oil droplet size from deepwater blowouts, the thickness of surfacing oil and the behavior of dissolvable components.
☐ Study bottom substrate dynamics that might affect submerged oil fate and behavior.
☐ Study how oil degrades in intertidal and shallow subtidal habitats (e.g., cobble, pebble, sand, mud, mussel beds, mangrove, and marsh).
TRANSPORT MODELS
☐ Use best available scientific data on oil weathering and fate to develop and improve transport model parameters (e.g., volatilization, solubilization, emulsification, biodegradation).
☐ Develop/improve oil trajectory and fate models that can be used during spill response to predict the behavior and transport of dispersed oil and verify/validate them in an appropriately designed experimental setting or during actual spills.
☐ Develop a decision template or conceptual model of the conditions under which oil might become submerged that considers oil properties and environmental characteristics.
OCEANOGRAPHIC MODELS
☐ Link ocean circulation models to observations (e.g., ocean observing systems) to better incorporate real-time data.
☐ Increase development and availability of high resolution nearshore models.

Integrate upper sea-surface turbulence, with particular emphasis on quantifying horizontal and vertical diffusivities and the rate of energy dissipation, to improve 3D and 4D spill transport models.
EMERGING CRUDE (including oil sands products (OSP) and Bakken, etc.)
Conduct research on the fate and transport of oil sands products in freshwater and marine environments.
Study the persistence of oil sands products in marine and freshwater environments.
Conduct research on the chemical and physical characteristics of various crudes (including blends of dilbit, synbit and Bakken crude) to better understand how to address spills.

9.3.4 Oil Spill Detection and Surveillance Priorities (Section 4.3.3.4)

This SRA principally refers to methods and equipment for characterizing and monitoring oil pre- and post-implementation of response options, and the detection of unknown discharges. This SRA includes surface and subsurface oil spill surveillance including devices, sensors, and systems for detecting and tracking oil spills, determining the area and thickness of the oil slick, and measuring the physical properties of the oil. Examples of equipment considered in this area are: surface oil spill tracking buoys; airborne remote sensors and data analysis systems; fluorometers and light-scattering sensors; and satellite remote sensing data and on/in-water oil detection devices with the ability to conduct nighttime and low light recovery operations. It includes research that provides information to support development of monitoring protocols for subsea and surface responses or improvements to existing ones such as the NRT Atypical guidance or the SMART guidance, as applicable. This SRA also includes evaluation of techniques for autonomous sensing operations and reporting from remote locations where logistical challenges limit human accessibility.

The priorities for this SRA focus on the development of improved technologies that can more rapidly and effectively identify the presence and the characteristics of oil in the water column and on the seafloor. These priorities would address some of the issues that arose from the *Deepwater Horizon* spill and may assist responders to react more effectively to future incidents. There are three subcategories for this SRA: Remote Detection, Monitoring, and Submerged Oil Detection.

REMOTE DETECTION
☐ Develop technologies that enable remote oil spill detection and mapping in low visibility conditions (e.g., night, fog).
☐ Develop enhanced technology for detecting oil under ice, encapsulated in ice, and floating within broken ice fields.
☐ Identify specific characteristics of crude oil exposed to the full microwave radiation spectrum (at hyperspectral intervals) and develop high resolution sensors for oil spill visualization, detection and quantification.
MONITORING
☐ Develop a refined SMART or equivalent protocol and operational procedures for use during subsea and surface responses based on recent experiences.
☐ Develop technology to rapidly analyze physio-chemical properties of spilled oil to improve decision-making regarding dispersant use and *in situ* burning (ISB).
☐ Develop new technologies to improve oil, dispersant, and oil/dispersant detection in the water column and on the seafloor, and for monitoring dispersant effectiveness in the field.
SUBMERGED OIL DETECTION
☐ Study the potential of acoustic systems and Light Detection and Ranging (LiDAR), both individually and as packaged suites, to detect submerged oil on the seafloor and in the water column.
☐ Develop new or improve existing chemical sensors for detecting submerged oil.
☐ Develop methods to calibrate the degree of oiling on snare sampling systems with the amount of oil on the seafloor or in the water column.

9.3.5 In- and On-water Containment and Recovery Priorities (Section 4.3.3.5)

This SRA includes the development of methods, equipment, and materials for physically containing and removing oil from the surface of the water, the water column, or on the bottom of the sea/river bed. This SRA focuses on improving traditional equipment such as booms, skimmers, and sorbent materials, as well as developing new approaches to surface containment, and equipment and systems specific to containment and recovery of subsurface oils.

The priority Research Needs in this SRA focus on the Arctic and other northern areas where cold water and ice will require innovative methods and technologies. There was also recognition of the need for better technologies to control and recover submerged oil given the greater emphasis on deep and ultra-deep water drilling. ICCOPR acknowledged the need for better testing protocols for new technologies and methods and identified research priorities that could improve laboratory and field testing. ICCOPR identified priorities in two subcategories: Control and Recovery Technology, and Recovery Operations and Testing.

CONTROL AND RECOVERY TECHNOLOGY
☐ Develop new mechanical recovery methods/technologies for logistically challenging (e.g., cold water, ice, broken ice) Arctic conditions.
☐ Develop new tools to control and recover oil that is submerged, suspended in the water column, or on the seafloor.
☐ Develop control and recovery capabilities for oil in river conditions with pack ice and ice flows.
RECOVERY OPERATIONS AND TESTING
☐ Develop/improve standardized testing protocols (especially for wave tanks) that yield cross-comparability of results and establish practical oil recovery limits that are achievable during response operations.
☐ Conduct field tests of cleanup techniques and create protocols for various habitats and conditions, including Arctic conditions.
☐ Develop surrogates for different types of oil to be used for training and for research and development testing.

9.3.6 Shore Containment and Recovery Priorities (Section 4.3.3.6)

This SRA covers new methods, treating agents, and equipment for removing oil from shorelines, as well as mitigating the environmental impact of oil that cannot be removed. Specifically, this SRA includes water washing and flooding techniques, the use of chemical treating agents, and novel applications of mechanical removal techniques and equipment. It also includes analysis, evaluation and decision-making (risk and benefits) for the use of active shoreline oil removal techniques versus passive naturally-occurring processes.

ICCOPR recognizes the difficulty of relying solely on physical recovery on shorelines. Therefore, priorities in this SRA focus on developing chemicals that prevent shoreline contact.

☐ Study the effectiveness of a range of technologies for shoreline or nearshore cleanup; including dispersants, bioremediation agents, shoreline cleaners, and mechanical methods.
☐ Study the effectiveness of surface washing for shoreline cleanup and develop standards for surface washing.
☐ Conduct research to assess the ability of chemicals to prevent oil from reaching or sticking to shorelines.

9.3.7 Dispersants Priorities (Section 4.3.3.7)

This SRA addresses the use of chemical products designed to interact with marine oil slicks by reducing the oil/water interfacial tension and breaking up the slick into tiny droplets with the aid of wave or other energy sources. Research areas for dispersants include: developing appropriate dispersant applications for cold weather and deep sea environments; increasing dispersant effectiveness for water surface and subsurface applications (e.g., effective on a wider viscosity and emulsification range, and calm sea conditions); reducing ecological effects of individual dispersant components and combined components in the water column; refining vessel, aircraft, and subsurface application methodologies and equipment; developing enhanced monitoring methods and systems for determining the effectiveness of surface and subsurface application of dispersants; determining how to distinguish physically versus chemically dispersed oil; studying the distribution and impact of the chemicals and dispersed oil in the environment; and understanding regional variations in dispersant performance and environmental effects. This SRA may include characterization to enhance the ability to predict dispersant effectiveness on various oil types and at varying application rates, including the effectiveness of dispersants on weathered/emulsified oils and in a range of water salinities. This SRA also encompasses studies to determine the suitability of subsea application of dispersants in the Arctic region where the unique conditions (e.g., shallow depths, water salinity, ice-infested water, under-ice discharges) could influence their fate and effects. An important supporting activity is the development of an information database on dispersant product effectiveness, application procedures, and effects. Since dispersants shift the risk from the surface to the water column, additional research is needed to address questions about the potential acute and chronic effects of dispersants on water column organisms and populations at various depths.

The *Deepwater Horizon* spill resulted in a very widespread use of dispersants and the first application of subsurface dispersants near the well head. This use of dispersants resulted in a significant interest in the effectiveness of dispersant use and its potential impacts. The importance of this SRA to future oil response is demonstrated by the large number of research needs identified. It is important to understand how dispersants behave in the environment and what their potential impacts are when applied. Specifically, ICCOPR identified Research Needs such as: dispersant use in Arctic conditions; the behavior of dispersants and dispersed oil in the environment; the toxicity of dispersants and dispersed oil; efficacy and effectiveness of dispersants; fate of dispersants and dispersed oil; and the application of subsurface dispersants.

This SRA includes six subcategories: Cold Weather and Ice Conditions, Behavior, Impacts, Efficacy and Effectiveness, Fate, and Subsurface. The Research Needs for this SRA include formulations appropriate for dispersant applications in cold weather and deep sea environments, and increasing dispersion effectiveness for water surface and subsurface applications.

COLD WEATHER AND ICE CONDITIONS
☐ Understand the "window of opportunity" for potential deployment of all dispersants in the Arctic and sub-Arctic.
☐ Study the best dispersants for different types of crude oil over a range of environmental conditions, including ice infested waters.
☐ Study the fate and effects of subsea application of dispersants in Arctic waters, including in ice infested water and under ice.
BEHAVIOR
☐ Study the transport and detection of oil, dispersants, and oil/dispersants in surface and subsurface environments, including deepwater.
☐ Study the impact of natural processes such as flocculation and hydrate encapsulation on oil and dispersed oil.
☐ Quantify degradation rates of chemically dispersed, physically dispersed, and undispersed oil, including biodegradation kinetics.
IMPACTS
☐ Improve protocols for testing toxicity of dispersants and other chemical agents to better represent real world exposure scenarios.
☐ Study and evaluate dispersant and dispersed oil chronic and sub-lethal effects on key species, and subsequent long-term ecological effects for varying real world exposure scenarios and durations.
☐ Collect existing dispersed oil toxicity data and studies to aid in risk-based decision-making regarding use of dispersants at spills.

EFFICACY AND EFFECTIVENESS
☐ Study the relative effectiveness of various surface dispersant delivery techniques/systems.
☐ Study the effects of subsea dispersant application on subsequent mechanical recovery of oil.
☐ Develop methods and quantify the factors needed to scale results of laboratory and wave tank experiments so that they become more accurate indicators of real world effectiveness.
FATE
☐ Develop studies to quantify the weathering rates and final fate of chemically dispersed vs. physically-dispersed oil droplets under different scenarios.
☐ Study the differences in the effects of photolysis on undispersed, chemically dispersed, and physically dispersed oil droplets.
☐ Study the adhesiveness of physically and chemically dispersed oil on organisms and habitats, including how adhesion changes over time and with oil type.
SUBSURFACE
☐ Study the relationship between subsurface application of dispersants, the characteristics of oil at the surface, and the fate of oil constituents, including Volatile Organic Compounds (VOCs), in the water column and at the surface.
☐ Develop conditions of operability for dispersant use in the subsea, including the characteristics of the most effective dispersant, application methods, and dispersant to oil ratios.
☐ Conduct research involving the application of dispersants at high pressure and low temperatures including quantifying the mixing energy at the wellhead.

9.3.8 *In Situ* Burning (ISB) Priorities (Section 4.3.3.8)

This SRA includes equipment and techniques required to ignite and sustain combustion of oil spills on the water, along shorelines, and on land. A source of ignition must be present for the mix of fuel (e.g., oil) and oxidant (e.g. oxygen) in a slick to burn. Because slick thickness is a key variable in determining whether the oil will burn, this research area includes development of equipment such as fire-resistant booms and herders to concentrate the slick thickness, and improved ignition devices. This SRA also includes developing knowledge of the conditions under which this equipment and technique can be applied effectively, including evaluation of use in frigid (i.e., Arctic) environments, where cold conditions and ice limit operational effectiveness of mechanical containment and recovery of spilled oil. This SRA also includes research to develop new methods to enhance burn efficiency and burn weathered, emulsified, and more viscous oils. Research into the production of residuals including soot and other ISB residues, and the techniques and equipment to recover these residues is also included in this SRA.

The priorities for this SRA address issues related to potential public health and environmental health from the burning of oil. The ICCOPR priorities also emphasize the need for improved technology to address containment, sustain burning and understand the potential for application of ISB in Arctic and other special environments. There are two subcategories: 1) Effectiveness and 2) Impacts and Planning and Technology.

EFFECTIVENESS AND IMPACTS
□ Develop improved pre- and post-spill plume modeling to determine whether an *in situ* burn should be conducted and facilitate decisions on measures to protect local populations, including the potential effect of "fall-out" from a smoke plume that goes over land-based subsistence resources.
□ Study *in situ* burning residues, especially toxicity, physical properties, and bioavailability of contaminants contained within the residue matrix, especially regarding potential benthic community effects.
□ Conduct additional research to improve *in situ* burning effectiveness in the Arctic and better define its applicability under various conditions.
PLANNING AND TECHNOLOGY
□ Conduct a comparative study of *in situ* burning vs. mechanical, chemical and natural attenuation methods in cleanup of wetlands or marshy areas.
□ Develop enhanced designs for containment of burning oil, such as reusable and high seas capable booms.
□ Develop methods to improve and sustain combustion of emulsions.

9.3.9 Alternative Chemical Countermeasures Priorities (Section 4.3.3.9)

This SRA includes the development and use of various spill response chemicals to treat oil slicks on the surface of the water making the oil more amenable to other recovery techniques, such as mechanical recovery and ISB. These chemicals include solidifiers, herding agents, elasticity modifiers, shoreline pre-treatment agents, and emulsion treating agents (demulsifiers). Development activities include improving chemical formulations, refining application techniques, and conducting studies of effectiveness and environmental effects.

ICCOPR priorities in this SRA recognize the potential of alternate chemical treatments to break emulsions and herd oil slicks to enhance other response techniques.

☐ Study the potential use of chemical herders to enhance response capabilities of *in situ* burning, recovery of oil-in-ice, or recovery of oil in confined/covered spaces.
☐ Study the value and impact of chemical herders with respect to the timing for deployment of various countermeasures, particularly with respect to a second-stage recovery effort during ice melt to target oil that had previously been entrained in sea ice.
☐ Conduct laboratory and field tests of chemical agents for breaking or inhibiting emulsions.

9.3.10 Oily and Oil Waste Disposal Priorities (Section 4.3.3.10)

This SRA includes study and development of analytical methods, procedures, equipment and techniques to manage and dispose of oil, oily water, oiled soils, and oiled debris recovered during both on-water and on land oil pollution incidents. Specific technologies include, but are not limited to, waste segregation, temporary storage, solidification and stabilization prior to landfill disposal or recycling, oil reclamation, incineration, and biological treatment (i.e., land farming and composting). It also includes techniques and equipment for onsite oil-water separation, filtration, and decanting operations that would reduce the volumes of oil/water material that would need to be handled, transported, and disposed.

ICCOPR priorities for this SRA focus on storage, waste issues and recycling.

☐ Develop innovative techniques for oil/water separation decanting systems for various oil types.
☐ Develop methods to recycle sorbents and reduce the waste created by using sorbents as a recovery option.
☐ Develop methods to temporarily store or dispose of recovered oil/pollutants in remote or harsh environments.

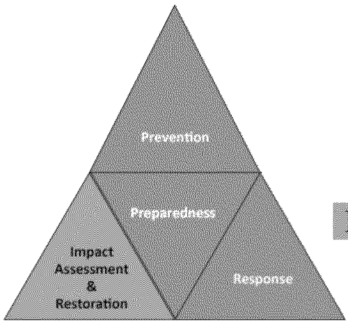
9.3.11 Bioremediation and Biodegradation Priorities (Section 4.3.3.11)

This SRA includes research and technology to exploit the capabilities of microorganisms and plants to accelerate the rate of degradation of oil typically through aerobic degradation, but also through anaerobic degradation processes. Bioremediation is largely an *in-situ* technology as *ex-situ* use requires excavation and further manipulations that may have a greater potential for environmental harm. Research and development opportunities include the development of methodologies for the use of nutrient enrichment and possibly microbes to accelerate the biodegradation process on land, a process called bio-augmentation. This topic area also covers research to understand the conditions needed for effective bioremediation in the presence or absence of dispersants, herders, and other chemical agents. In areas such as coastal wetlands, where stranded oil may have penetrated into the anaerobic subsurface, this research area would include studies to wick the oil up to the surface where aerobic conditions and nutrient enrichment may result in enhanced biodegradation. This SRA also includes development of methodologies to apply bioremediation for more effective response and restoration efforts. For purposes of this OPRTP, bioremediation includes phytoremediation (remediation using plants), a longer-term restoration technique.

ICOCPR priorities under this SRA focus on gaining a better understanding of the bioremediation process and the factors associated with its use in oil spill remediation.

- Study the relative effectiveness and environmental impacts of bioremediation technologies.
- Develop an improved understanding of bioremediation processes with a wider range of conditions/environments (e.g., cold water), multiple types of oil, nutrient enrichment, toxicity and eutrophication.
- Study the factors controlling bioavailability of petroleum hydrocarbons in estuarine and freshwater sediments.

9.4 Injury Assessment and Restoration Priority Research Needs



INJURY ASSESSMENT AND RESTORATION

9.4.1 Environmental Impacts and Ecosystem Recovery Priorities (Section 4.3.4.1)

This SRA includes laboratory research, field studies, and modeling efforts to better understand and predict the short- and long-term effects of oil spills at the ecosystem level. It includes research into the short- and long-term recovery of various types of environments and the chronic effects of oil spills on habitat, species, recovery and rehabilitation of wildlife, and community structures. This SRA includes the effects of the oil and the countermeasures and cleanup techniques used to remove the oil. It also includes research to determine the rate of ecosystem recovery both with and without countermeasures and cleanup.

The priorities selected by ICCOPR reflect the continued need to assess the short- and long-term effects of the *Deepwater Horizon* oil spill through the NRDA process. ICCOIPR identified priorities within six subcategories for this SRA due to the large number of identified Research Needs: 1) Species Impacts; 2) Toxicological and Sub-lethal Impacts; 3) Submerged and Submerged Oil Impacts; 4) Ecosystem and Habitat Impacts; 5) Recovery; and 6) Risk Assessment and Impact Metrics.

SPECIES IMPACTS
□ Study the effect of exposure to oil on: physiological functions of organisms (immune, reproductive, and other vital systems); potential impacts on individual fitness; and population vitality rates, abundance and trends.
□ Develop an increased understanding of the environmental effects of *in situ* burning, chemical dispersants and herding agents on Arctic ecology.
□ Conduct research that examines the state of knowledge of specific NRDA metrics that would help identify specific population, physiological, habitat, and exposure data to support future NRDA activities in Arctic areas that are likely to be explored/developed for oil and gas extraction in the near to mid-term.

TOXICOLOGICAL AND SUB-LETHAL IMPACTS
☐ Develop relevant biological markers of exposure and guidelines for their use.
☐ Conduct research on key species to determine the long-term, sub-lethal effects of short-term exposure to oil.
☐ Study the bioavailability and toxicity of oil sands products in freshwater and marine environments.
SUNKEN AND SUBMERGED OIL IMPACTS
☐ Develop an understanding of the pathways of exposure and mechanisms of chronic toxicity of submerged oil to benthic communities.
☐ Develop approaches for long-term monitoring of the impacts of submerged oil spills after termination of cleanup efforts.
☐ Develop an understanding of the potential threats of chronic releases from sediments containing oil and oily residues.
ECOSYSTEM AND HABITAT IMPACTS
☐ Develop relevant exposure conditions (spatially and temporally) and examine connections between exposure and ecological effects.
☐ Develop an understanding of trophic and habitat linkages among organisms to incorporate into models predicting cascading effects.
☐ Develop an understanding of the difference between oil effects and natural stressors by assessing community structure and function for different habitats.
RECOVERY
☐ Study recovery rates of injured habitats using different types of oils and methods (e.g., previous spills, mesocosm, field studies).
☐ Develop conceptual models of service loss and recovery from key habitats, and gather the information necessary to parameterize recovery models.
☐ Conduct a study comparing environmental injury footprints and ecosystem recovery times after implementation of various response technologies and techniques.

RISK ASSESSMENT AND IMPACT METRICS
□ Develop models to estimate injury to natural resources encompassing a range of exposure scenarios to biota at different life stages.
□ Conduct research to determine the best metrics for assessing injury and damages to natural resources.
□ Conduct single species toxicity research to assess population effects and help risk-based decision-making during an event.

9.4.2 Environmental Restoration Methods and Technologies Priorities (Section 4.3.4.2)

This SRA includes development of methods and technologies to facilitate and accelerate the recovery of resources following an oil spill. It includes research into the effectiveness of approaches for environmental restoration. It also includes evaluations and comparisons of the factors affecting success of the restoration methods and technologies. It also involves studying previous restoration efforts, as well as natural recovery, to better understand ways to improve or enhance future recovery from oil spills.

ICCOPR recognized that the *Deepwater Horizon* oil spill, as well as other marine and onshore spills, offer opportunities to assess restoration techniques and improve the state of the art.

□ Develop methods for restoration assessment (including establishing indicators and applying performance metrics) and estimation of restoration cost.
□ Conduct comparative analysis of restoration vs. natural attenuation.
□ Study the factors associated with long-term restoration success.

9.4.3 Human Safety and Health Priorities (Section 4.3.4.3)

This SRA includes studies on the effects of spilled oil and oil spill response activities on human health and safety for both workers and the public. It includes the study of oil weathering throughout the water column and the potential concerns relative to worker health and safety. It focuses on the development of monitoring instruments, procedures, and processes to inform personnel engaged in oil spill response activities, as well as the general public, who could be affected by the oil spill and response options. It also includes studies of the safety of fish and shellfish in a spill area to determine if they are safe to market and consume. Research on seafood safety may include petrochemical toxicology and profiling, risk analysis, sampling and testing methodology development, and risk communications.

The research priorities focus on worker safety and human exposure, as well as on seafood safety. The *Deepwater Horizon* spill has provided opportunities for short- and long-term monitoring of workers and the public related to these topics. There are two subcategories to this SRA: Safety and Human Exposure.

SAFETY
□ Develop technologies, methods, and standards for protecting on-scene personnel, including the incorporation of training, adequate supervision, information databases, protective equipment, maximum exposure limits, and decontamination procedures.
□ Study the levels of oil constituents, including Volatile Organic Compounds (VOCs), throughout the water column under different dispersant application scenarios (e.g., subsea, surface) and establish their contribution to potential worker health and safety issues.
□ Conduct research on the short- and long-term safety of seafood following a spill or fisheries closure and develop methods to communicate these to the public.
HUMAN EXPOSURE
□ Develop the framework needed to conduct rapid research response on human exposure during oil spills.
□ Study the short- and long-term impacts to humans from exposure to contaminants from oil spills (e.g., dermal, oral (through seafood), and respiratory).
□ Study the toxicological effects and the causal or correlative relationships between chemical (i.e., oil and dispersants) exposure and human health.

9.4.4 Sociological and Economic Impacts Priorities (Section 4.3.4.4)

This SRA includes studies on how oil spills and the response to oil spills affect the sociological fabric of communities and their economies. Disciplines encompassed in this research area include sociology, economics, behavioral sciences, political science, and law. It also involves studies on risk communication and community resilience.

The priorities in this SRA identify the need for improving communication methods and understanding the human and community impacts of a spill, particularly by improving research frameworks and studying previous spills. There are two subcategories in this SRA: Community and Economic Impacts, and Human Impacts.

COMMUNITY AND ECONOMIC IMPACTS
Develop more effective models/frameworks for community/stakeholder involvement in oil spill planning, response and restoration.
Develop improved methods for communicating risks and tradeoffs to various audiences, including tradeoffs of mechanical recovery, dispersant use, and other technologies.
Study cumulative community vulnerability and resilience to past spills, including social impacts.
HUMAN IMPACTS
Study the resilience of social-ecological systems to environmental disasters, including the degree of impact on human well-being from ecosystem services losses.
Determine human/community impacts associated with a spill, including subsistence losses and culturally-significant natural resource injuries.
Study the effects of media and community groups in shaping individual and public perceptions of a spill's impact.

References

American Petroleum Institute (API). 2012. *API 2012 Oil and Gas Overview webpage.* Accessible from: http://www.api.org/oil-and-natural-gas-overview.aspx.

Association of American Railroads. *2015a. U.S. Rail Crude Oil Traffic*. June 2015. Available online: https://www.aar.org/BackgroundPapers/US Rail Crude Oil Traffic (June 2015).pdf.

Association of American Railroads. *2015b. Moving Crude Oil Safely by Rail*. June 2015. Available online: https://www.aar.org/BackgroundPapers/Moving Crude Oil Safely by Rail (July 2015).pdf.

Australian Maritime Safety Authority (AMSA). 2010. *Response to the Montara Wellhead Platform Incident. Report of the Incident Analysis Team*. March 2010. Available online from: http://www.amsa.gov.au/forms-and-publications/publications/montara_iat_report.pdf.

Battelle. 2005. *Hazardous Materials Serious Crash Analysis: Phase 2 Final Report.* Prepared for the DOT Federal Motor Carrier Safety Administration. April 2005. 134 pp. Available from: http://ntl.bts.gov/lib/51000/51300/51392/Hazardous-Materials-Serious-Crash-Analysis-Phase2-April2005.pdf.

Bosma, S. 2012. The Regulation of Marine Pollution Arising from Offshore Oil and Gas Facilities – An Evaluation of the Adequacy of Current Regulatory Regimes and the Responsibility of States to Implement a New Liability Regime. In: *Australian & New Zealand Maritime Law Journal*. Vol. 26:1. Available from: http://ssl.law.uq.edu.au/journals/index.php/maritimejournal/article/view/179/221.

Bureau of Reclamation Glossary. Retrieved September 21, 2012, from website: http://www.expertglossary.com/definition/.

Burkhard, J., P. Stark, and L. Smith. 2010. *Oil Well Blowout and the Future of Deepwater E & P.* IHS Cambridge Energy Research Associates– Energy Strategy, May 2010.

Bureau of Safety and Environmental Enforcement (BSEE). 2012. *"BAA Proposed Research on Oil Spill Response Operations."*

Cantwell, M. 2012. 2012. *Introduction of Oil Spill Research and Technology Act of 2012 (S. 3298).* Introduced June 15, 2012. Available for viewing online at: http://www.govtrack.us/congress/bills/112/s3298 and from Senator Catwell's website at: http://www.cantwell.senate.gov/public/index.cfm/press?ID=707fda1b-2646-4b3b-b671-ef7a85b37c1d.

Center for Spills in the Environment (CSE). 2012. *"Alberta Oil Sands Workshop for Maine DEP and U.S. EPA Region 1."* Portland, ME. December 4-5, 2012. http://crrc.unh.edu/workshop/cse/alberta-oil-sands-training.

Center for Spills in the Environment (CSE). 2013. *"Oil Spill Dispersant Research Workshop Report."* Baton Rouge, LA, March 12-13, 2013, http://crrc.unh.edu/workshop/cse/oil-spill-dispersant-research-forum.

Center for Spills in the Environment (CSE). 2013. *"Alberta Oil Sands Workshop for Washington State Department of Ecology, the Regional Response Team 10 and the Pacific States/British Columbia Oil Spill Task Force".* Seattle, WA. April 16-17, 2013. http://crrc.unh.edu/workshop/cse/oil-sands-products-forum-working-group.

Chambers, R. 2009. *Editorial Introduction: Vulnerability, Coping and Policy. Institute of Development Studies (IDS) Bulletin*, Vol., 20, Issue No. 2, Institute of Development Studies, 1-7. 1759-5436. mp200002001.x. Available from: http://dx.doi.org/10.1111/j.1759-5436.1989.mp20002001.x.

Coastal Response Research Center (CRRC). 2006. *Research & Development Needs For Addressing the Human Dimensions of Oil Spills*. University of New Hampshire http://www.crrc.unh.edu/publications/human_dimensions_report.pdf.

Coastal Response Research Center. (November 2003). "*Research and Development Priorities: An Oil Spill Workshop.*" http://crrc.unh.edu/workshop/crrc/research-development-priorities-oil-spill-workshop.

Coastal Response Research Center. (September 2005). *"Workshop: Research & Development Needs for Making Decisions Regarding Dispersing Oil."* http://crrc.unh.edu/workshop/crrc/research-development-needs-making-decisions-regarding-dispersing-oil.

Coastal Response Research Center. (June 2006). *"Workshop: Research Needs for Addressing the Human Dimensions of Oil Spills."* http://crrc.unh.edu/workshop/crrc/research-needs-human-dimensions-oil-spill-response.

Coastal Response Research Center. (December 2006). *"Submerged Oil Workshop Report."* http://crrc.unh.edu/workshop/crrc/submerged-oil-state-practice.

Coastal Response Research Center. 2009 *"R&D Priorities: Oil Spill Workshop".* March 2009 http://crrc.unh.edu/workshop/crrc/2009-research-development-priorities.

Coastal Response Research Center. 2011. *"Coordinating R&D on Oil Spill Response in the Wake of Deepwater Horizon."* July 2011. Available at: http://crrc.unh.edu/workshop/crrc/coordinating-rd-oil-spill-response-wake-deepwater-horizon.

Coastal Response Research Center. 2012. *"The Future of Dispersant Use in Oil Spill Response Initiatives."* March 2012. Available at: http://crrc.unh.edu/workshop/crrc/future-dispersant-use-spill-response.

Coastal Response Research Center. 2014. *"Environmental Data Management Workshop."* September 2014. Available at: http://crrc.unh.edu/workshops/EDDM.

Commonwealth Scientific and Industrial Research Organization (CSIRO). 2015. "*Offshore oil and Gas*." http://www.csiro.au/en/Research/EF/Areas/Oil-gas-and-fuels/Offshore-oil-and-gas.

Council on Environmental Quality (CEQ). 1970. National Oil and Hazardous Materials Pollution Contingency Plan. June 1970

Department of Energy (DOE). 2008a. *"2007 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program."* DOE/NETL-2007/1294. January 2008a

Department of Energy (DOE). 2008b. *"2008 Annual Plan for the Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program."* DOE/NETL-2008/1315. August 2008

Department of Energy (DOE). 2008c. *"2009 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report."* DOE/NETL-2009/1343. December 2008

Department of Energy (DOE). 2009. *"2010 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report."* DOE/NETL-2009/1384. December 2009

Department of Energy (DOE). 2011. *"2011 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report To Congress."* August 2011

Department of Energy (DOE). 2012. *"2012 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report To Congress."* August 2012

Department of Energy (DOE). 2013. "*2013 Annual Plan Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, Report To Congress*." June 2013.

Energy Policy Act. *2005. Section 999A (b)(4) DOE National Energy Technology Laboratory Complementary Research Program".*

Environmental Protection Agency, Office of Research and Development. 2011. *"Draft Oil Spill Research Strategy."* January 12, 2011

Environmental Protection Agency. 2014. *"EPA Office of Solid Waste - Personal Communication."*

Etkin, D.S. 2011. Personal Communication. September 26, 2011.

Etkin, D.S. 2009. *Analysis of U.S. Oil Spillage*. API Publication 356. The American Petroleum Institute, Regulatory and Scientific Affairs Department. Washington, D.C.: American Petroleum Insitute. 86 p. August 2009. Available from: http://www.api.org/environment-health-and-safety/clean-water/oil-spill-prevention-and-response/spills-and-releases.aspx.

EOP-OST. 1969. *The Oil Spill Problem: First Report of the President's Panel on Oil Spills*, U.S. Executive Office of the President (EOP) Office of Science & Technology (OST), Washington, D.C. 1969

Executive Order 12777. *Implementation of §311 of the Federal Water Pollution Control Act of 1972, as amended, and the Oil Pollution Act 18 October 1991.*October 18, 1991.

Executive Order 13286 of February 28, 2003. *Amendment of Executive Orders, and Other Actions, in Connection With the Transfer of Certain Functions to the Secretary of Homeland Security*. (68 Fed. Reg. 10619), March 5, 2003.

Federal Railroad Administration (FRA). 2012. *"2012 FRA Research Review Conference."* Available at: https://www.fra.dot.gov/Page/P0486.

Federal Railroad Administration (FRA). 2014. *"Federal Railroad Administrator Prepared Remarks - 50th Meeting of the Railroad Safety Advisory Committee."* October 31, 2013

Federal Railroad Administration (FRA). 2015. *"Tank Car Safety."* https://www.fra.dot.gov/Page/P0515.

Federal Water Pollution Control Administration (FWPCA). 1968. *National Multiagency Oil and Hazardous Materials Contingency Plan*. September 1968. NTIS Ascension Number PB-216 561

Gulf of Mexico Research Initiative. 2010. *"Gulf of Mexico Research Initiative: Research Themes."* May 2010. http://research.gulfresearchinitiative.org.

Gulf of Mexico Research Initiative. 2015. *"Gulf of Mexico Research Initiative: Program Update."* http://research.gulfresearchinitiative.org/research-awards/.

Hamberger, E. R. and M.D. Manion. 2011. *Joint Statement Before the U.S. House of Representatives Committee on Transportation and Infrastructure. Hearing on the Rail Safety Improvement Act of 2008, March 17, 2011*. Association of American Railroads, 22 pp. Available from: www.aar.org/.../~/.../2011-03-17-testimony-railsafetyact.pdf.ashx.

Hersman, D.A.P. 2011. *Highway Accident Report – Rollover of a Truck-Tractor and Cargo Tank Semitrailer, Indianapolis, Indiana, October 22, 2009*. Opening Statement at the 26 July 2011 NTSB Board Meeting. Available from: http://www.ntsb.gov/news/speeches/hersman/daph110726o.html.

H.R. 3609 (107th): *Pipeline Safety Improvement Act of 2002*. Amendment of Title 49, U.S.C. Available from: www.gpo.gov.

H.R. 5782 (109th): *Pipeline Inspection, Protection, Enforcement, and Safety Act of 2006*. Amendment of Title 49, U.S.C. Available from: www.gpo.gov.

House of Representatives, Committee on Science & Technology. 2009. *"A New Direction for Federal Oil Spill Research & Development."* Serial No. 111-29. June 4, 2009.

House of Representatives, Committee on Science & Technology. 2010. *"Deluge of Oil Highlights Research & Technology Needs for Effective Cleanup of Oil Spills."* (June 2010)

International Association of Oil and Gas Producers. 2012. *"International Association of Oil and Gas Producers - Joint Industry Programme Solicitation for Expression of Interest (EOI) on Arctic Oil Spills"* February 2012

Interagency Coordinating Committee on Oil Pollution Research.1992. *"Oil Pollution Research and Technology Plan."* April 1992.

Interagency Coordinating Committee on Oil Pollution Research. 1997. *"Oil Pollution Research and Technology Plan."* April 1997

Interagency Coordinating Committee on Oil Pollution Research. 2003. "Report to Congress on the *Interagency Coordinating Committee on Oil Pollution Research [Biennial Report to Congress for FY 2001 & 2002]."October 2003*

Interagency Coordinating Committee on Oil Pollution Research. 2010. *"Interagency Coordinating Committee on Oil Pollution Research Public Meetings – West."* May 2010

Interagency Coordinating Committee on Oil Pollution Research. 2010. *"Interagency Coordinating Committee on Oil Pollution Research Public Meetings – East."* September 2010

Interagency Coordinating Committee on Oil Pollution Research. 2010. *"Interagency Coordinating Committee on Oil Pollution Research Public Meetings – Gulf."* November 2010

Interagency Coordinating Committee on Oil Pollution Research. 2010. *"Public Meetings, Letters, and Reports Submitted to ICCOPR as Part of the R&T Planning Process."*

International Oil Spill Conference (IOSC). 2014. *"2014 Conference On-Water and Aerial Technical Demonstration: A Complete Spill Response System."*

International Tanker Owners Pollution Federation (ITOPF). 2015. *"Country Profiles."* Available at: http://www.itopf.com/knowledge-resources/

International Tanker Owners Pollution Federation (ITOPF). 2015. Oil Tanker Spill Statistics 2014. ITOPF, London, United Kingdom. January 2015.

Joint Industry Task Force Oil Spill Preparedness and Response. 2011. Progress Report on Industry Recommendations to Improve Oil Spill Preparedness and Response. November 30, 2011.

Michel, J., T. Gilbert, D.S. Etkin, R. Urban, J. Waldron, and C.T. Blocksidge. 2005. *An Issue Paper Prepared for the 2005 International Oil Spill Conference*: *"Potentially Polluting Wrecks in Marine Waters:*. International Oil Spill Conference Proceedings: May 2005, Vol. 2005, No. 1, pp. 1-40. **doi:** http://dx.doi.org/10.7901/2169-3358-2005-1-1.

National Research Council Marine Board. 1993. *Review of the Interagency Oil Pollution Research and Technology Plan: First Report on the Committee on Oil Spill Research and Development*. Prepared by the National Academy Press, Washington D.C. Marine Board, Commission on Engineering and Technical Systems, National Research Council. 54 pp. Available from: http://www.uscg.mil/iccopr/files/Marine Board Review-First Report-1993.pdf.

National Research Council Marine Board. 1994. *Review of the Interagency Oil Pollution Research and Technology Plan: Final Report on the Committee on Oil Spill Research and Development*. Prepared by the National Academy Press, Washington D.C. Marine Board, Commission on Engineering and Technical Systems, National Research Council. 8 pp. Available from: http://www.uscg.mil/iccopr/files/Marine Board Review-Final Report-1994.pdf.

Marine Mammal Commission. 2010. *"Letter to LT Tracy Wirth: Comments for the Interagency Coordinating Committee on Oil Pollution Research on Priorities for Oil Pollution Research."* September 9, 2010

Marine Mammals Commission. 2011. *"Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in the Gulf of Mexico: A Statement of Research Needs."* August 2011

Massey, A. 2012. Interspill 2012 Keynote Speaker – Chief Executive, UK Maritime & Coast Guard Agency. Available from: http://www.interspill.org/previous-events/2012/.

McCoy, M.A. and J.A. Salerno (Eds.). 2010. *IOM (Institute of Medicine): Assessing the effects of the Gulf of Mexico oil spill on human health: A summary of the June*

2010 workshop. August 10, 2010. Washington, D.C: The National Academies Press. Available from: http://www.iom.edu/Reports/2010/Assessing-the-Effects-of-the-Gulf-of-Mexico-Oil-Spill-on-Human-Health.aspx.

National Academy of Sciences Institutes of Medicine. 2010. *"National Academy of Sciences Institutes of Medicine Research Priorities for Assessing Health Effects from the Gulf of Mexico Oil Spill."*

National Commission on BP Deepwater Horizon. 2011. *"National Commission on BP Deepwater Horizon - Final Report."* January 2011

National Commission on BP Deepwater Horizon. 2011. *"National Commission on BP Deepwater Horizon – Response/Clean-up Technology Research & Development and the BP Deepwater Horizon Oil Spill." Staff Working Paper No. 7.* Updated January 2011

National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. 2011. *Deepwater: The Gulf Oil Disaster and the Future of Offshore Drilling. Report to the President.* ISBN: 978-0-16-087371-3, 398 pp. Available from: http://www.oilspillcommission.gov/final-report.

National Petroleum Council. 2015. *"Arctic Potential – Realizing the Promise of U.S. Arctic Oil and Gas Resources."* March 27, 2015

National Research Council. 2013. *"An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico."*

National Research Council. 2014. *Responding to Oil Spills in the U.S. Arctic Marine Environment.* Washington, DC: The National Academies Press. Available from: http://www.nap.edu/catalog/18625/responding-to-oil-spills-in-the-us-arctic-marine-environment

National Research Council. 2005. *"Oil Spill Dispersants: Efficacy and Effects."* Washington, DC: The National Academies Press. Available from: http://www.nap.edu/catalog/11283/oil-spill-dispersants-efficacy-and-effects.

National Science and Technology Council, Subcommittee on Ocean Science and Technology. 2010. *"Deepwater Horizon Oil Spill Principal Investigator Workshop, October 25-26, 2011: Final Report."* Washington, DC. 91pp.

NOAA. 2014. *45 Years after the Santa Barbara Oil Spill, Looking at a Historic Disaster Through Technology.* January 26, 2014. Webpage: http://response.restoration.noaa.gov/about/media/45-years-after-santa-barbara-oil-spill-looking-historic-disaster-through-technology.html . Last accessed May 20, 2015.

O'Brien, M. 2011. *New Horizons? Dealing with Major Oil Spills from Non-Tanker Sources.* Keynote presentation at the Petroleum Association of Japan (PAJ) - Oil Spill Workshop 2011, Tokyo, Japan, March 2nd

Ocean Energy Safety Advisory Committee. (April 2012). *"Letter of Recommendations to BSEE Department of the Interior."*

Ocean Energy Safety Advisory Committee. 2012. "Letter *of Recommendations to BSEE Department of the Interior.*" October 15, 2012

Ocean Energy Safety Advisory Committee. 2013. "Letter *of Recommendations to BSEE Department of the Interior.*" January 25, 2013

Oil & Gas IQ. 2015. The 10 Biggest Oil Spills in World History (online). Last accessed April 10, 2015 at.: http://www.oilandgasiq.com/integrity-hse-maintenance/articles/the-10-biggest-oil-spills-in-world-history-part-8/Paleontological Research Institution (PRI) History of Oil Website – available from: http://www.priweb.org/ed/pgws/history/pennsylvania/pennsylvania.html.

Pacific States/British Columbia Oil Spill Task Force. 2010. *"Pacific States/British Columbia Oil Spill Task Force Letter to Interagency Coordinating Committee on Oil Pollution Research."* May 19, 2010

Parfomak, P.W. 2011. *Keeping America's Pipelines Safe and Secure: Key Issues for Congress.* Washington D.C. UNT Digital Library. July 11, 2011. Available from: http://digital.library.unt.edu/ark:/67531/metadc96681/.

Pees, Samuel T. 2004. "Oil History: The Drake Chapters." Website last accessed July 20, 2015 at http://www.petroleumhistory.org/OilHistory/pages/drake/drake.html.

PHMSA. 2012. *Government and Industry Pipeline Forum, Arlington, VA, July 18-19, 2012.*

Picou, J.S. and D.A. Gill. 1996. *The Exxon Valdez Oil Spill and Chronic Psychological Stress.* In: *American Fisheries Society Symposium.* 18:879-893.

Pine, John C. 2006. "Hurricane Katrina and Oil Spills: Impact on Coastal and Ocean Environments." *Oceanography* 19.2 (2006): 37-39. The Oceanography Society. Available from: http://www.tos.org/oceanography/archive/19-2_pine.pdf.

Pipeline and Hazardous Materials Safety Administration (PHMSA). 2014. *"Office of Pipeline Safety - Personal Communications."*

Pipeline and Hazardous Materials Safety Administration (PHMSA). 2015. http://www.phmsa.dot.gov/.

Pipeline and Hazardous Materials Safety Administration (PHMSA). 2007. Safe Pipelines FAQs. Website last updated August 29, 2007. Website available at: http://phmsa.dot.gov/about/faq.

Pipeline and Hazardous Materials Safety Administration (PHMSA). 2015. Pipeline Incident 20 Year Trends (searchable database last accessed April 10, 2015. Available at: https://hip.phmsa.dot.gov/analyticsSOAP/saw.dll?Portalpages.

Prince William Sound Oil Spill Recovery Institute. 2010. *"Research Plan 2011-2015."* February 2010

Prince William Sound Regional Citizens' Advisory Council. 2013. *"Oil Spill Simulants Materials: Workshop Proceedings."* May 2013 Final

Ramseur, J.L. 2011. *Liability and Compensation Issues Raised by the 2010 Gulf Oil Spill*. Congressional Research Service Report R41679, 27 pp. March 11, 2011. Available from: http://assets.opencrs.com/rpts/R41679_20110311.pdf.

Ramseur, J L. 2012. *Oil Spills in U.S. Coastal Waters: Background and Governance*. Congressional Research Service. January 11, 2012

Ritchie, L.A., D.A. Gill and J.S. Picou. 2011. *The BP Disaster as an Exxon Valdez Rerun Contexts*. *American Sociological Association*, 10:3, pp. 30-35. ISSN 1536-5042, electronic ISSN 1537-6052. Available from: http://contexts.sagepub.com. doi: 10.1177/1536504211418454.

Rothblum, A.M. 2000. *Human Error and Marine Safety*. Paper presented at the *National Safety Council Congress and Expo*, Orlando, FL, Oct. 13-20, 2000. Available from: http://www.bowles-langley.com/wp-content/files_mf/humanerrorandmarinesafety26.pdf.

Steering Committee for the NASA Technology Roadmaps: National Research Council of the National Academies. 2012. *NASA Space Technology Roadmaps and Priorities: Restoring NASA's Technological Edge and Paving the Way for a New Era in Space*. 122 pp. ISBN 978-0-309-25362-8. Available from: http://www.nap.edu/catalog.php?record_id=13354.

Thébaud, O., D. Bailly, J. Hay, and J. Pérez. 2003 "*The cost of oil pollution at sea: an analysis of the process of damage valuation and compensation following oil spills.*" 13 pp. Available from: http://otvm.uvigo.es/investigacion/informes/documentos/archivos/Prestige_Hayetal.pdf.

Transportation Research Board (TRB). 2013. *"Effect of Diluted Bitumen on Crude Oil Transmission Pipelines Special Report 311."* Available from http://www.nap.edu/catalog/18381/trb-special-report-311-effects-of-diluted-bitumen-on-crude-oil-transmission-pipelines.

Title 33 U.S. Code Chapter 40 Subchapter IV 2761. 1990. *"Oil Pollution Act of 1990."* August 1990.

Ultra-Deepwater Advisory Committee. 2011. *"2011 Plan: Comments, Findings and Recommendations."* April 2011.

Ultra-Deepwater Advisory Committee. 2012. *"2012 Plan: Comments, Findings and Recommendations."* March 2012.

Ultra-Deepwater Advisory Committee. 2012. *"2013 Draft Plan: Findings and Recommendations."* November 2012.

U.S. Arctic Research Commission (USARC). (July 2010). *"U.S. Arctic Research Commission - White Paper."*

U.S. Coast Guard. 2005. *Investigation into the Explosioni and Sinking of the Chemical Tanker Bow Mariner in the Atlantic Ocean on February 28, 2004 with Loss of Life and Pollution.* December 14, 2005.

U.S. Coast Guard. 2008a. *Incident Specific Preparedness Review (ISPR) M/V Cosco Busan Oil Spill in San Francisco Bay: Report on Initial Response Phase*. January 11, 2008

U.S. Coast Guard. 2008b. *Incident Specific Preparedness Review (ISPR) M/V Cosco Busan Oil Spill in San Francisco Bay: Part II and Final Report*. May 7, 2008

U.S. Coast Guard (USCG). 2011a. *"Deepwater Horizon Incident Specific Preparedness Review: Final Report."* January 2011

U.S. Coast Guard (USCG). 2011b. *"On Scene Coordinator Report on Deepwater Horizon Oil Spill."* August 17, 2011

U.S. Coast Guard (USCG). 2012. *Improvements to Reduce Human Error and Near Miss Incidents: 2012 Report to Congress, May 7, 2012*. 74 pp. Pub. L. 111-281, title VII – Oil Pollution Prevention, § 703 – Improvements to reduce human error and near miss incidents.

U.S. Congress. *1990. The Oil Pollution Act of 1990.* P.L. 101-380. 33 U.S.C. 2701, Chapter 40 – Oil Pollution, Subchapter 1 – Oil Pollution Liability and Compensation (§§2701- 2720).

U.S. Department of Transportation. 2014. *"Emergency Restriction/Prohibition Order [USDOT Emergency Order on Transport of Bakken Crude Oil.]"* EO Number: DOT-OST-2014-0067. May 7, 2014

U.S. Energy Information Administration (EIA). 2012. *Annual Energy Outlook 2012 with Projections to 2035*. DOE/EIA-0383(2012) / June 2012. 252 pp.

U.S. Energy Information Administration (EIA). 2015. *Annual Energy Outlook 2015 with Projections to 2040*. DOE/EIA-0383(2015) / April 2015. 154 pp. Available at: www.eia.gov/forecasts/aeo.

U.S. Geological Survey (USGS). 2011. *"An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas."* June 2011

U.S. Government Accountability Office (GAO). 2012. *"Oil Dispersants Report."* GAO-12-58. May 30, 2012

VanHaverbeke, Mark. 2012. *Oil and Hazardous Materials Spill Response Technology Development, Strategic Plan*. CG-D-07-12. U.S. Coast Guard Research and Development Center, New London, CG. May 2012.

Vocke, William T. 2014. "*Building a Legacy of Research Coordination: A History of the ICCOPR from Exxon Valdez to Present Day*". International Oil Spill Conference Proceedings: May 2014, Vol.2014, No.1, pp93-101 Allen Press. **doi:** http://dx.doi.org/10.7901/2169-3358-2014.1.93.

Walker, A.H, D.L. Ducey Jr., S.J. Lacey, and J.R. Harrald. 1994. *Implementing an Effective Response Management System: A White Paper Prepared for the 1995 International Oil Spill Conference*. Technical Report IOSC-001. (API Publication No. 4621A. American Petroleum Institute, Washington, DC. December 1994,

Watkins, J.A. 2012. *BSEE reply to Ocean Energy Safety Advisory Committee Letter of Recommendations to BSEE Department of the Interior, dated May 17, 2012.* Letter dated August 10, 2012

Watkins, J.A. 2013. *BSEE reply to Ocean Energy Safety Advisory Committee Letter of Recommendations to BSEE Department of the Interior, dated October 15, 2012.* Letter dated January 4, 2013

Watkins, J.A. 2013. *BSEE reply to Ocean Energy Safety Advisory Committee Letter of Recommendations to BSEE Department of the Interior, dated January 25, 2013.* Letter dated August 14, 2013

Webler, T. and F. Lord. 2010. Planning for the human dimensions of oil spills. Environmental Management 45: 723-738. February 19, 2010. Available from: http://seri-us.org/content/planning-for-the-human-dimensions-of-oil-spills.

Webler, T., S. Tuler, F. Lord, and K. Dow. 2010. *Guidance for Incorporating Human Impacts and Vulnerabilities in Marine Oil Spill Contingency Planning: Final Report*. Report 10-003. December 2010. Greenfield, MA: Social and Environmental Research Institute. 42 pp.

White, I.C. 2002. *Factors Affecting the Cost of Oil Spills*. GAOCMAO Conference, Muscat, Oman, 12-14 May 2002. ITOPF, London. Available from: http://www.itopf.com/fileadmin/data/Documents/Papers/costs02.PDF.

White, I.C. & F. C. Molloy. 2003. *Factors that Determine the Cost of Oil Spills*. International Oil Spill Conference Proceedings: April 2003, Vol. 2003, No. 1, pp. 1225-1229. **doi:** http://dx.doi.org/10.7901/2169-3358-2003-1-1225.

Wood & Associates. 2005. *M/V Selendang Ayu Incident After Action Review*. USCG – MSO Anchorage. July 31, 2005.

Wreck Oil Removal Program. 2009. *"Wreck Oil Removal Program Overview."*

APPENDICES

A. Numbered List of Standing Research Areas (SRAs)

B. ICCOPR Standing Research Areas – 2014 Database

C. ICCOPR Standing Research Areas – 2014 Sources

D. Survey Technical Report

E. Sample of Research Priority Survey

F. Sample of Survey Data

THIS PAGE INTENTIONALLY LEFT BLANK.